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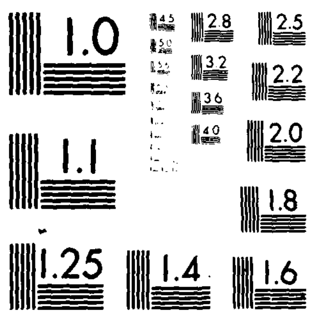

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AN EVALUATION OF THE HYDRODYNAMIC STABILITY AND OPERATIONAL SUITABILITY OF A TOWED CTD DEPRESSOR SYSTEM THROUGH USE OF AN ACOUSTIC TRACKING RANGE.

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Thomas H. Hesselbacher
George J. Ranes

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TABLE OF CONTENTS

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NØØØ14-79-C-Ø8Ø3
per George Ranes - MAR, Rockville, MD
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LIST OF ILLUSTRATIONS

Section 1

INTRODUCTION

In September 1979, MAR, Incorporated was contracted by the Naval Ocean Research and Development Activity (NORDA) to perform an acoustic tracking test of a depressor designed to house a CTD instrumentation package. This report describes the planning, preparation and results of the test conducted at the BARSTUR range in June 1980.

1.1 BACKGROUND

In March 1978, the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) was tasked by the Naval Oceanographic Office (NAVOCEANO) to provide a controllable depth towed depressor to house a conductivity, temperature and depth (CTD) instrument system. In addition to sensors located at the depressor, provision for two sets of remote sensors to be located on the towcable was requested.

The depressor was towed in the deep-water basin at DTNSRDC and was delivered to NAVOCEANO in early 1979.

NORDA was requested by NAVOCEANO to assist with the evaluation of the system in an open ocean environment. MAR was tasked by NORDA to conduct this evaluation.

1.2 SYSTEM DESCRIPTION

1.2.1 Depressor

The depressor is a modified mine sweeping body employing an inertially actuated rudder for lateral stability and a closed loop servo-control system for depth and elevator control. A sketch showing the principal dimensions of the body is presented in Figure 1-1. The section labeled 1 in the figure will house the Neil Brown Instrument Systems, Inc., CTD sensor electronics and digital multiplexed telemetry system. Section 2 is a free-flooded area available for installation of the tracking pinger and section 3 houses the body's control electronics.

The depressor can be operated either at constant, commandable depth or can be commanded to cycle up and down about a mean depth by inputting a wave form signal through the control system.

1.2.2 Towcable

The towcable is a double-armored cable containing nine electrical conductors, with an overall diameter of 8.8 mm (0.347 in.). The cable has an air weight of 2.87 N/meter and minimum breaking strength of 42.3 kN.

1.2.3 Remote Sensors and Mounts

The remote sensors are capable of being employed at varying distances along the towcable with maximum vertical separations from the depressor of 10 m and 20 m.

The mount is designed to place the sensors forward of the towcable and is attached by means of a clamp. The mount is free to pivot around the towcable and is aligned into the flow during towing by the drag on the remote sensor cable attached between the aft end of the mount and a bracket clamped to the towcable at the depressor.

1.2.4 Depth Control System

The depth control system consists of: (1) an inbody water-tight housing containing a servo-motor which actuates the horizontal tail flap to vary the depth of the depressor; (2) a shipboard control unit from which the depth of the depressor is ordered; (3) a power supply to provide power to the depressor electronics; and (4) a function generator to control the depth of the depressor through a range of frequencies and amplitudes.

A more complete description of the depressor system can be found in Reference 1.

1.3 OBJECTIVES

Although the depressor was designed and demonstrated to be very stable during tow-basin tests, an at-sea demonstration was felt to be necessary to determine the spatial and temporal scales of stability when the system was subject to the perturbating influence of sea state, operational towcable lengths and the inclusion of the remote sensors.

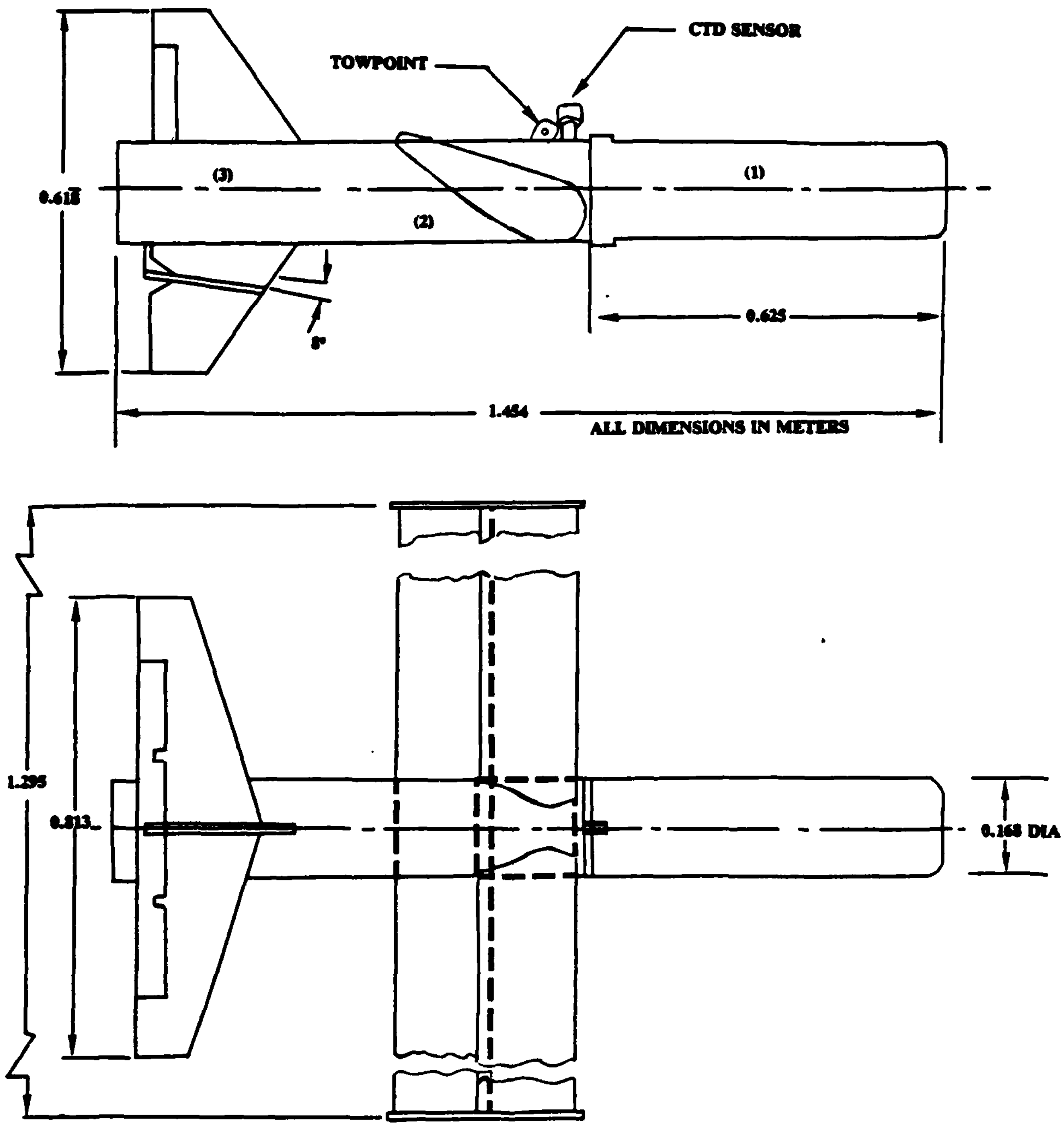


Figure 1-1. Towed CTD Depressor

Section 2

PREPARATION, PLANNING, AND CONDUCT OF TEST

Although the acoustic tracking test was the culmination of almost a full year's effort on the part of many people, only a brief synopsis is included in this report.

2.1 PREPARATION

Original planning called for the utilization of the AUTEC tracking range, however, difficulties in ship scheduling required the use of a Pacific Ocean range and after discussions on achievable accuracies and considerations of cost, the decision was made to use BARSTUR, off the island of Kauai. Figure 2-1 illustrates the location and topography of the range.

MAR had planned to design and develop a tracking pinger system to install in the depressor however, the decision to use BARSTUR made possible the use of MK 72 Mod O sonar transmitter system. This system was provided and modified by the Naval Undersea Warfare Engineering Station (NUWES) Detachment Hawaii. Modifications included waterproofing the pinger and rearranging the electronics and battery configuration to fit inside the nose section of the body. Acoustic testing performed by MAR in November 1979 showed that the body's fiberglass fuselage seriously degraded acoustic transmissions through it and so provision was made for free contact of the pinger face with the water.

In addition to the towed body, the tow ship, USNS DeSteiguer, was outfitted with a pinger by NUWES, to permit simultaneous tracking of the ship and the depressor.

2.2 PLANNING

The plan generated for the BARSTUR test was designed to exercise the depressor's capabilities over the full range of envisioned uses.

Details of the test plan may be found in Reference 2, but in general, testing was scheduled for three eight-hour periods, during which time the ship steamed back and forth over the range at three different speeds while the depressor was ordered to various depths and ordered to cycle at three different frequencies and two different amplitudes.

The test plan was executed during the period 24-26 June 1980 and a description of the test follows.

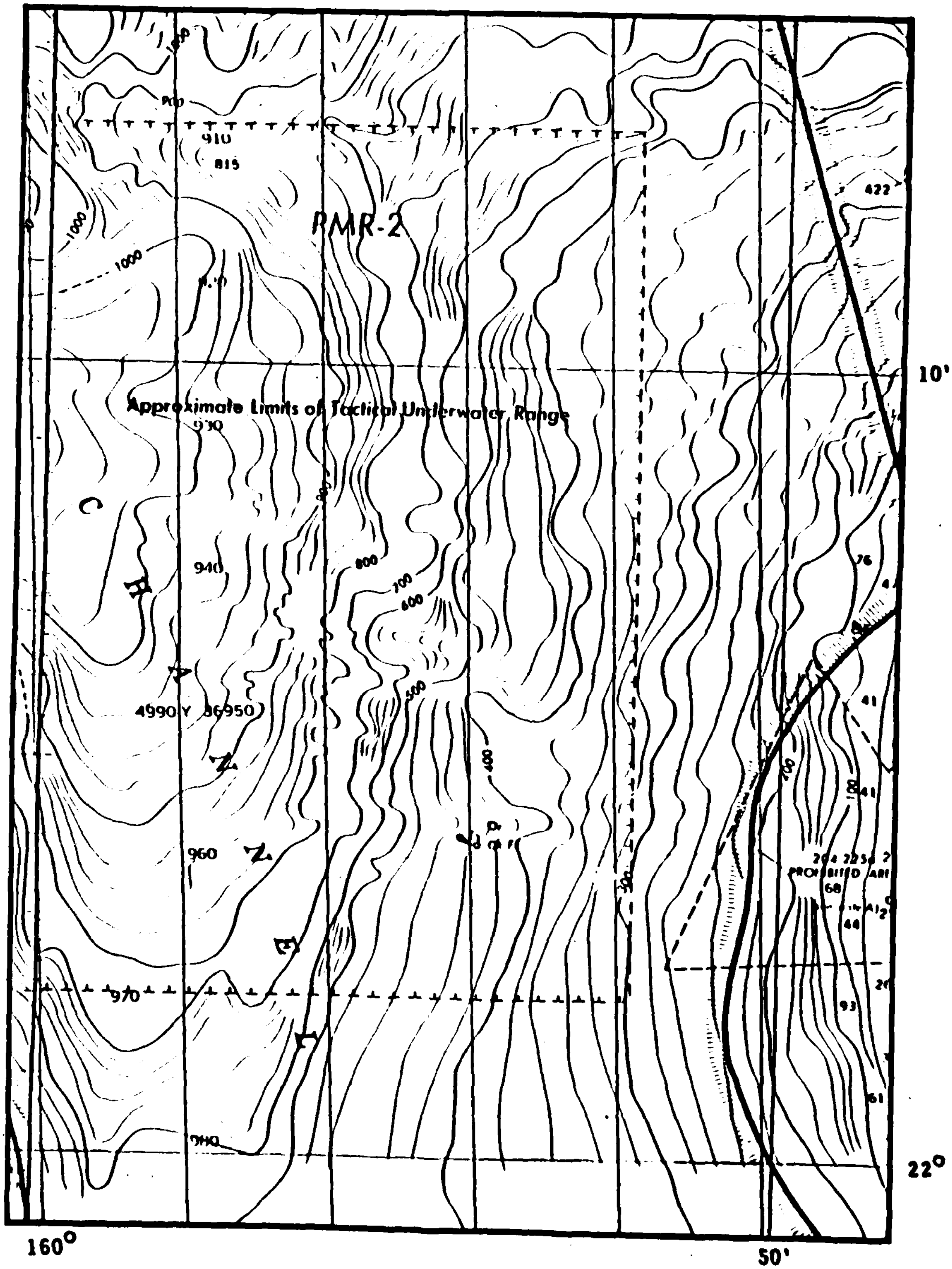


Figure 2-1. BARSTUR Tracking Range Location

2.3 CONDUCT OF TEST

2.3.1 Day One (6/24/80)

During the pre-deployment system checkout it was discovered that the in-line tensiometer was not working. To minimize the risk of excessive cable loads, the system was deployed without the attachment of either of the remote sensors.

Tracking was started at 1638 local time and the first day's testing was completed at 2320.

Several modifications to the test plan were required during the test. The first nine segments, shown in Table 2-1, were planned to be run at three knots. However, it was difficult for the ship to maintain this speed and so it was changed to four knots. Also, the ordered depths had to be changed.

When the test plan was generated, the ordered depths selected were based on predicted performance curves contained in Reference 1 and reproduced here as Figures 2-2a through 2-2d. Even after accounting for the removal of the remote sensors, the depressor could not reach the shallowest depths at any speed, as predicted by these curves for as yet undetermined reasons.

Modifications were made to the test sequence and variable settings were selected as shown in Table 2-2.

2.3.2 Day Two (6/25/80)

Prior to this day's testing, a Dillon tension guage was obtained from PMRF, Barking Sands. One remote sensor was installed at 10 m above the towpoint. Four extra test segments were planned in order to check out the Dillon meter as compared to predicted tensions.

A ship's steering casualty forced a delay of about two hours, and testing commenced at 1118 local time.

The four additional segments were completed and the second day's scheduled testing was started, again with modification to the ordered depths. After completion of the three constant depth segments, it was discovered that the body would not cycle. The problem was traced to the shipboard function generator, and the decision was made to proceed with the remaining scheduled constant depth runs from the second day and to continue with the third day's constant depth segments.

The completed test sequence and variable settings are listed in Table 2-3.

Table 2-1. Test Period One Variable Settings

Scope = 100m

Speed (kts)	Ordered Depth (m)	Elev. Input Freq.	Elev. Input Amplitude
3	10	--	--
3	45	--	--
3	25	--	--
3	--	0.003	max
3	--	0.003	1/2 max
3	--	0.007	max
3	--	0.007	1/2 max
3	--	0.01	max
3	--	0.01	1/2 max
7	15	--	--
7	55	--	--
7	35	--	--
7	--	0.003	max
7	--	0.003	1/2 max
7	--	0.007	max
7	--	0.007	1/2 max
7	--	0.01	max
7	--	0.01	1/2 max

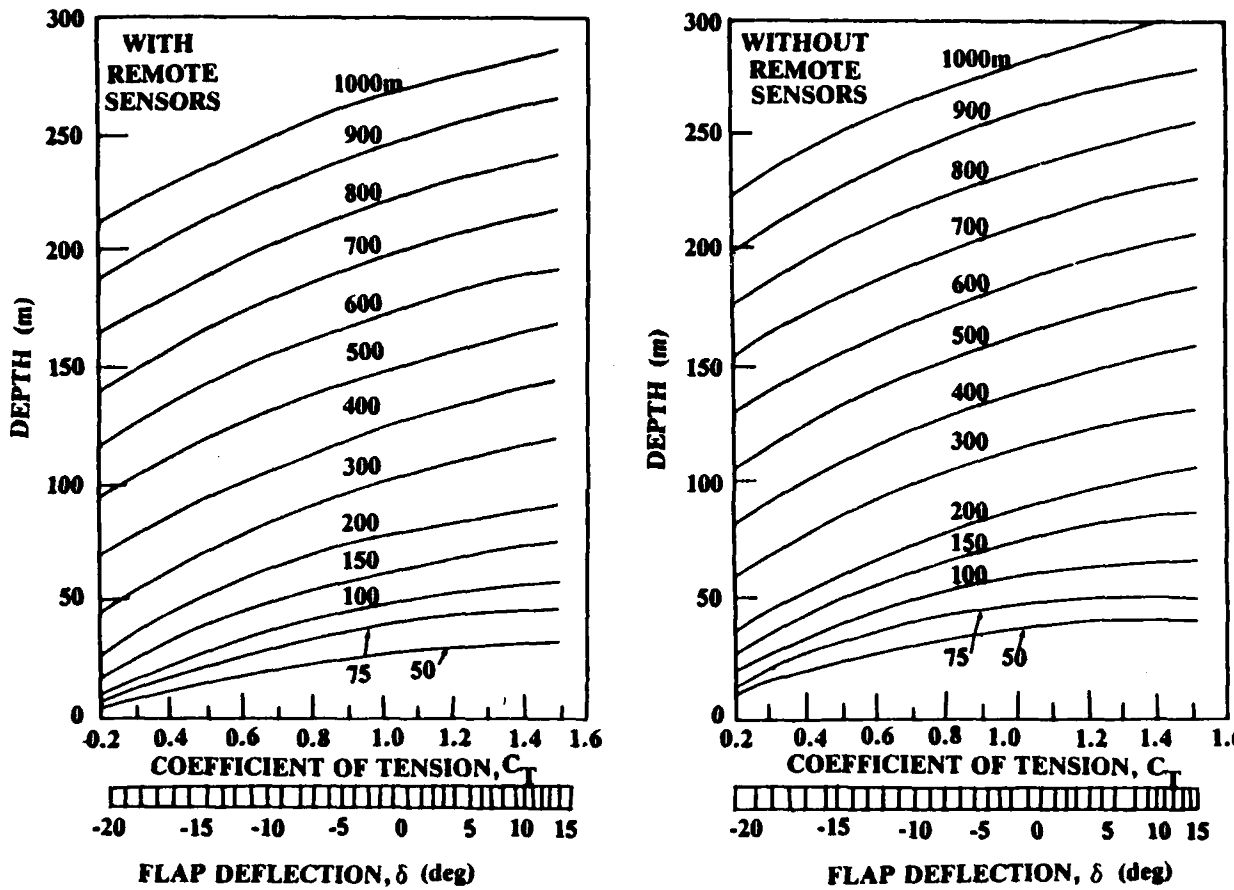


Figure 2-2a. 4 Knots

Figure 2-2. Predicted Depth as a Function of Depressor Coefficient of Tension for Various Wetted Towcable Lengths and Speeds.

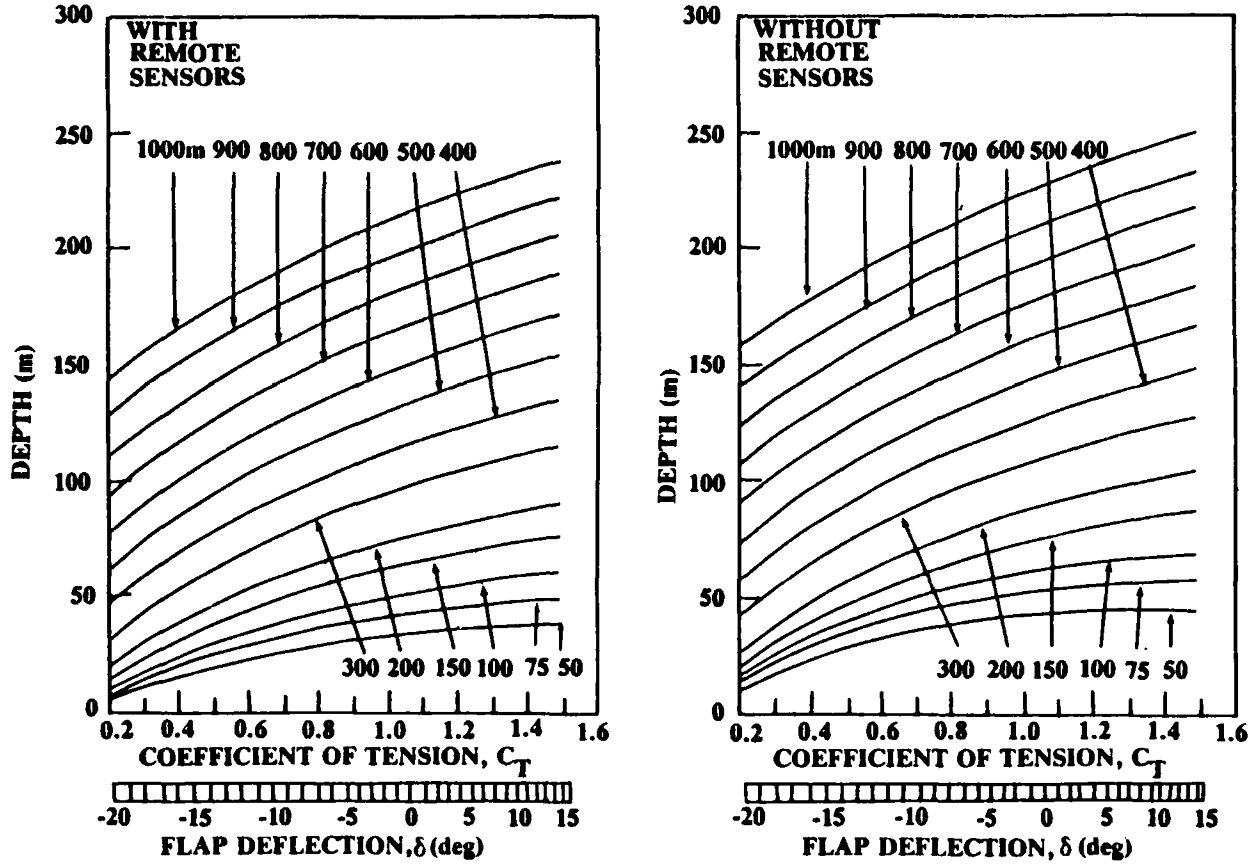


Figure 2-2b. 6 Knots

Figure 2-2. Predicted Depth as a Function of Depressor Coefficient of Tension for Various Wetted Towcable Lengths and Speeds (Continued).

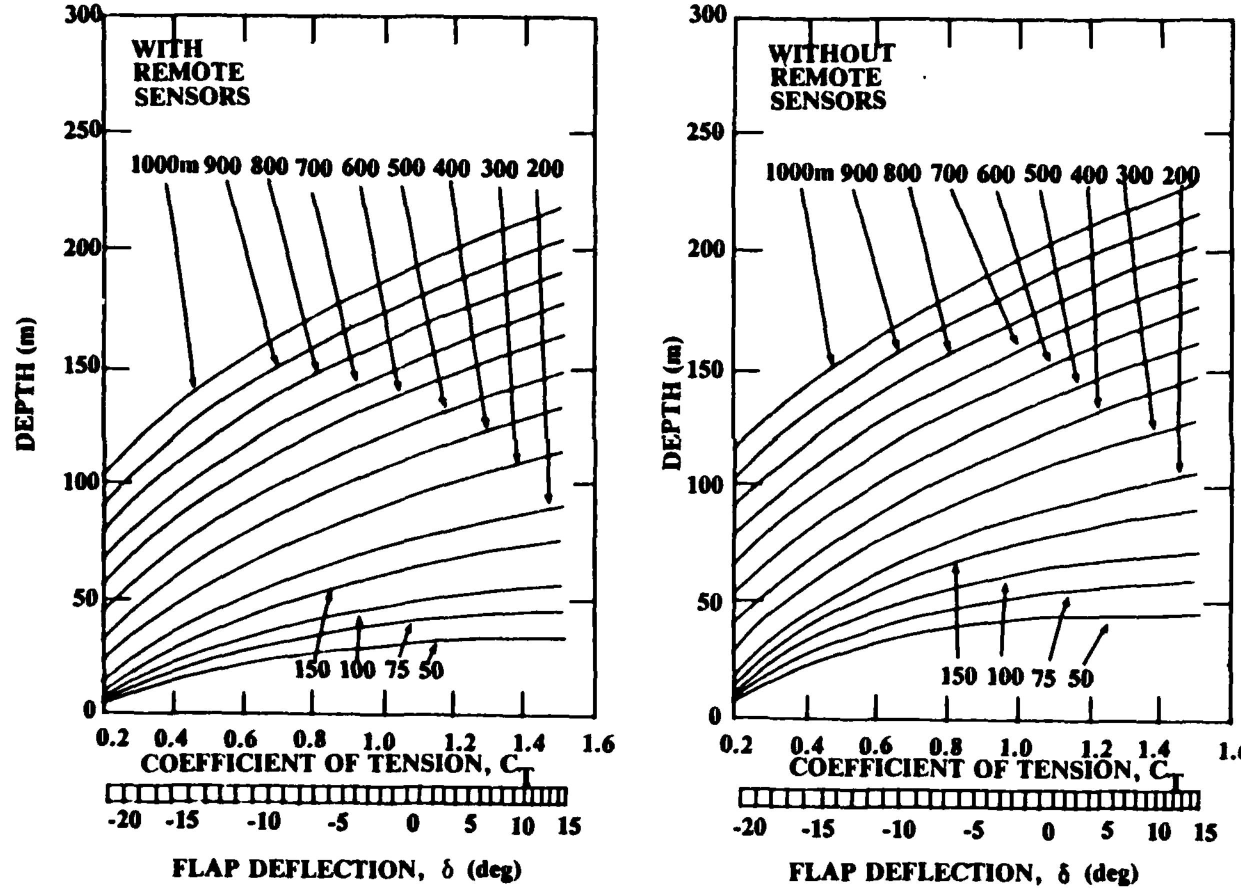


Figure 2-2c. 8 Knots

Figure 2-2. Predicted Depth as a Function of Depressor Coefficient of Tension for Various Wetted Towcable Lengths and Speeds (Continued).

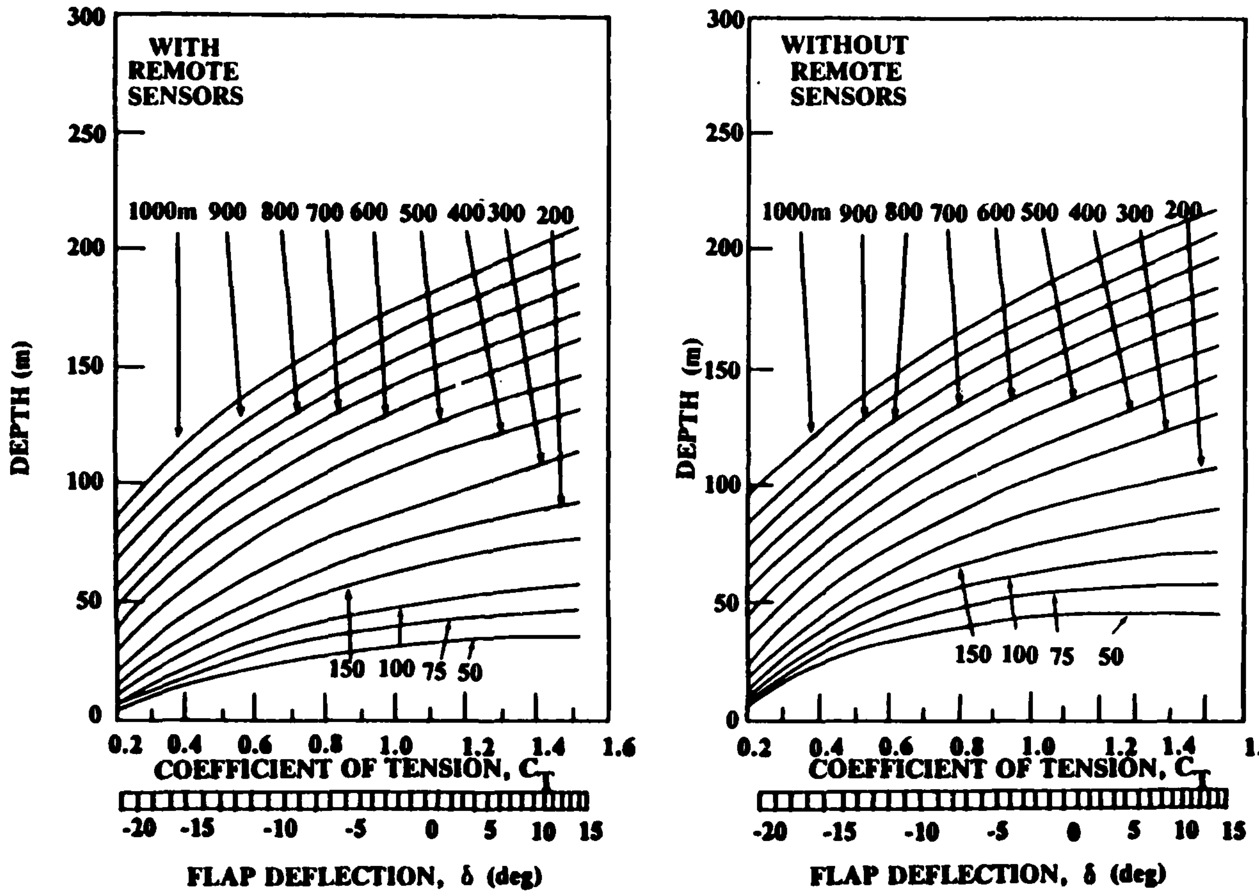


Figure 2-2d. 10 Knots

Figure 2-2. Predicted Depth as a Function of Depressor Coefficient of Tension for Various Wetted Towcable Lengths and Speeds (Continued).

Table 2-2. Completed Test Segments, Day One

24 June 1980

Segment	COMEX	FINEX	Scope	Speed	Depth	Frequency	Amplitude
AB	02.38.01	02.51.00	100m	4	55	--	--
BC	02.54.01	03.08.00		4	45	--	--
CD	03.09.01	03.22.00		4	50	--	--
DE	03.26.01	03.39.00		4	50	.003	max
JK	03.45.01	03.50.00		6	28	180° TURN TO PORT	
EF	03.53.01	04.14.00		4	50	.003	1/2 max
FG	04.17.01	04.30.00		4	50	.007	max
GH	04.30.02	04.43.00		4	50	.007	1/2 max
HI	04.43.02	04.56.00		4	50	.01	max
PQ	04.58.01	05.04.00		6	50	180° TURN TO STBD	
		ABORTED					
IJ	05.08.01	05.11.00		4	50	.01	1/2 max
IJ	05.23.01	05.35.00		4	50	.01	1/2 max
KL	05.44.01	05.56.00		7	20	--	--
VAA	06.00.01	06.10.00		6	40	180° TURN TO STBD	
LM	06.14.01	06.27.00		7	65	--	--
MN	06.30.01	06.43.00		7	40	--	--
NO	07.04.01	07.24.00		7	40	.003	max
OP	07.25.01	07.46.00		7	40	.003	1/2 max
QR	08.01.01	08.13.01		7	40	.007	max
RS	08.14.01	08.26.00		7	40	.007	1/2 max
ST	08.27.01	08.39.00		7	40	.01	max
TU	08.40.01	08.52.00		7	40	.01	1/2 max
UV	09.08.10	09.20.00		7	40	--	--

Table 2-3. Completed Test Segments, Day Two

25 June 1980

Segment	COMEX	FINEX	Scope	Speed	Depth	Frequency	Amplitude
2-1	21.18.01	21.30.00	100m	4	50	--	--
2-2	21.34.01	21.46.00		6	45	--	--
2-3	21.51.01	22.03.00		8	25	--	--
2-4	22.11.01	22.16.00		6	45	180° TURN TO PORT	
AB	22.22.01	22.34.00		10	20	--	--
DE	22.45.02	22.50.00		8	60	TURN 180° TO STBD	
BC	22.53.01	23.04.00		10	60	--	--
CD	23.07.01	23.20.00		10	40	--	--
HI	23.28.02	23.33.00		10	40	TURN 180° TO STBD	
						FNC GEN NOT WORKING	
EF	0.15.01	00.24.00		10	40	.003	max
NO	01.09.01	01.21.00	500m	4	110	--	--
OP	01.24.01	01.37.00		5	160	--	--
PQ	01.39.01	01.50.00		5	130	--	--
(3) CD	02.05.02	02.15.00		7	100	--	--
(3) BC	02.19.02	02.31.00		7	150	--	--
(3) EF	02.32.01	02.37.00		7	150	TURN 180° TO STBD	
(3) NO	02.41.01	02.53.00		10	150	--	--
(3) PQ	02.56.01	03.09.00		10	100	--	--
(3) MN	03.20.01	03.33.00		10	70	--	--

2.3.3 Day Three (6/26/80)

The faulty signal generator was replaced with a unit the DeSteiguer had onboard and the test segments omitted from the previous day and the cycling segments scheduled for day three were run with both remote sensors installed at two and ten meters.

The completed sequence and variable settings are shown in Table 2-4.

Table 2-4. Completed Test Segments, Day Three

26 June 1980

Segment	COMEX	FINEX	Scope	Speed	Depth	Frequency	Amplitude
DE	01.50.01	02.10.01	500m	7	125	.003	max
FG	02.11.01	02.30.01		7	132	.003	1/2 max
IJ	02.31.10	02.35.30		7	133	TURN 180° TO PORT	
GH	02.43.01	02.55.00		7	125	.007	max
HI	02.58.01	03.10.02		7	125	.007	1/2 max
KL	03.12.03	03.25.01		7	125	.01	1/2 max
JK	03.34.03	03.46.03		7	125	.01	max
QR	03.51.03	04.11.05		10	125	.003	max
ST	04.23.04	04.35.00		10	125	.007	max
VW	04.37.01	04.49.00		10	125	.01	max
WX	04.51.02	05.02.03		10	125	.01	1/2 max
UV	05.12.01	05.24.00		10	125	.007	1/2 max
RS	05.25.01	05.45.00		10	125	.003	1/2 max
(2) EF	06.14.01	06.34.00	100m	10	50	.003	max
(2) GH	06.36.02	06.49.00		10	50	.007	max
(2) JK	06.58.01	07.10.00		10	50	.01	max
(2) KL	07.12.01	07.24.00		10	50	.01	1/2 max
(2) IJ	07.38.01	07.50.00		10	50	.007	1/2 max
(2) FG	07.52.01	08.12.00		10	50	.003	1/2 max
3-1	08.26.01	08.38.00		10	50	.003	max

Section 3

DATA ACQUISITION AND ANALYSIS

During the tracking test at BARSTUR, data was obtained from two independent sources.

3.1 RANGE DATA

The primary data obtained by the range were time series of the three dimensional positions of the towship and the depressor. These data were returned in several different forms including plotboard charts, paper printouts, computer plots and digital tapes.

3.2 SHIPBOARD DATA

The data recorded onboard the DeSteiguer consists primarily of the standard feedback data from the body, which are depth, elevator angle and delta depth.* These were recorded continuously on strip chart recorders and single point records were hand written for each test segment.

3.3 ANALYSIS

The volume of data obtained from the test preclude a detailed analysis of each segment due to time and cost constraints. However, five segments were selected for examination and cross-comparison of the range and shipboard data.

3.3.1 Procedure

The five chosen segments listed in Table 3-1 were selected on the basis of impressions and observations made during the test, however, no attempt was made to select the "best looking" runs.

During a majority of the four knot segments, the flap angle readout indicated large deflections of the elevator signifying that the depressor was having difficulty maintaining depth. This problem also occurred during the shallowest seven and ten knot segments. These segments were eliminated on this basis because they are outside the recommended operating regime.

* NOTE: Delta depth is an internal measure of the body's depth keeping ability and is equal to the ordered depth minus measured depth from the pressure transducer.

Table 3-1. Selected Test Segments

SEGMENT	SCOPE	SPEED	ORDERED DEPTH	INPUT FREQUENCY	INPUT AMPLITUDE
MN 6/24	100m	7 kts	38m	--	--
BC 6/25	100m	10 kts	60m	--	--
NO(3) 6/25	500m	10 kts	156m	--	--
DE 6/26	500m	7 kts	125m	0.003 Hz	max
JK 6/26	500m	7 kts	125m	0.01 Hz	max

The five segments selected give good coverage to the depth range of particular interest, as well as yielding information dealing with the full range of variable settings tested.

The computer plots of the depressor's depth produced at the range are plotted on too gross a scale to see much detail, so they were replotted on a finer scale after first subtracting the ordered depth from each point. As can be seen from Figures 3-1 through 3-4, there is quite a bit of noise in the raw data. A three second running average was used to produce the smoothed traces of Figures 3-5 through 3-9. The strip chart recordings of delta depth are included as Figures 3-10 through 3-14.

Each of the segments is analyzed qualitatively in the following.

3.3.2 Results

3.3.2.1 Segment MN, 6/24

Several features stand out when examining the overlay of the range data and the delta depth data shown in Figure 3-15.

First, the delta depth trace is much smoother. This is understandable since the range data is digital and the delta depth signal is analog. Although response time of the pressure transducer circuit has not been measured, it is felt to be on the order of 100 msec, so the delta depth trace is felt not to be smoothed by response delay.

Secondly, the general overall agreement between the two series is quite good, primarily in the 120 to 600 second segment of data. With a few exceptions, the data agree to within approximately one meter. After examining the computer plots produced at the range, which show the positions of the tracking hydrophones, it was concluded that the areas of poor agreement of the curves could be traced to the range data. During the period from 120 seconds to 540 seconds the depressor was being tracked by the same three hydrophones, while during the remaining time periods it was being tracked by different hydrophones. It is a well known characteristic of acoustic tracking ranges for tracked vehicles to appear to suddenly change position as different hydrophone arrays come into use. Although this problem degrades the overall positioning accuracy, the relative point-to-point accuracy appears to be well within the ± 3 feet limit requested of the range. Another possibility that was considered that might have explained the offsets seen in portions of the range data was the existence of a complex thermal structure. XBT launches were made each day, and an examination of the traces shown as Figures 3-16 through 3-18 shows this not to be the case.

The short period (~6-10 sec) oscillations shown by much of the delta depth trace could arise from two sources. First, this might be an indication of coupling of the body with the ship motions resulting from state 3 seas. Secondly, the data log for this run indicates that the flap angle for this test segment was at a large value meaning that the ordered depth was marginally within the body's capability at this speed and scope.

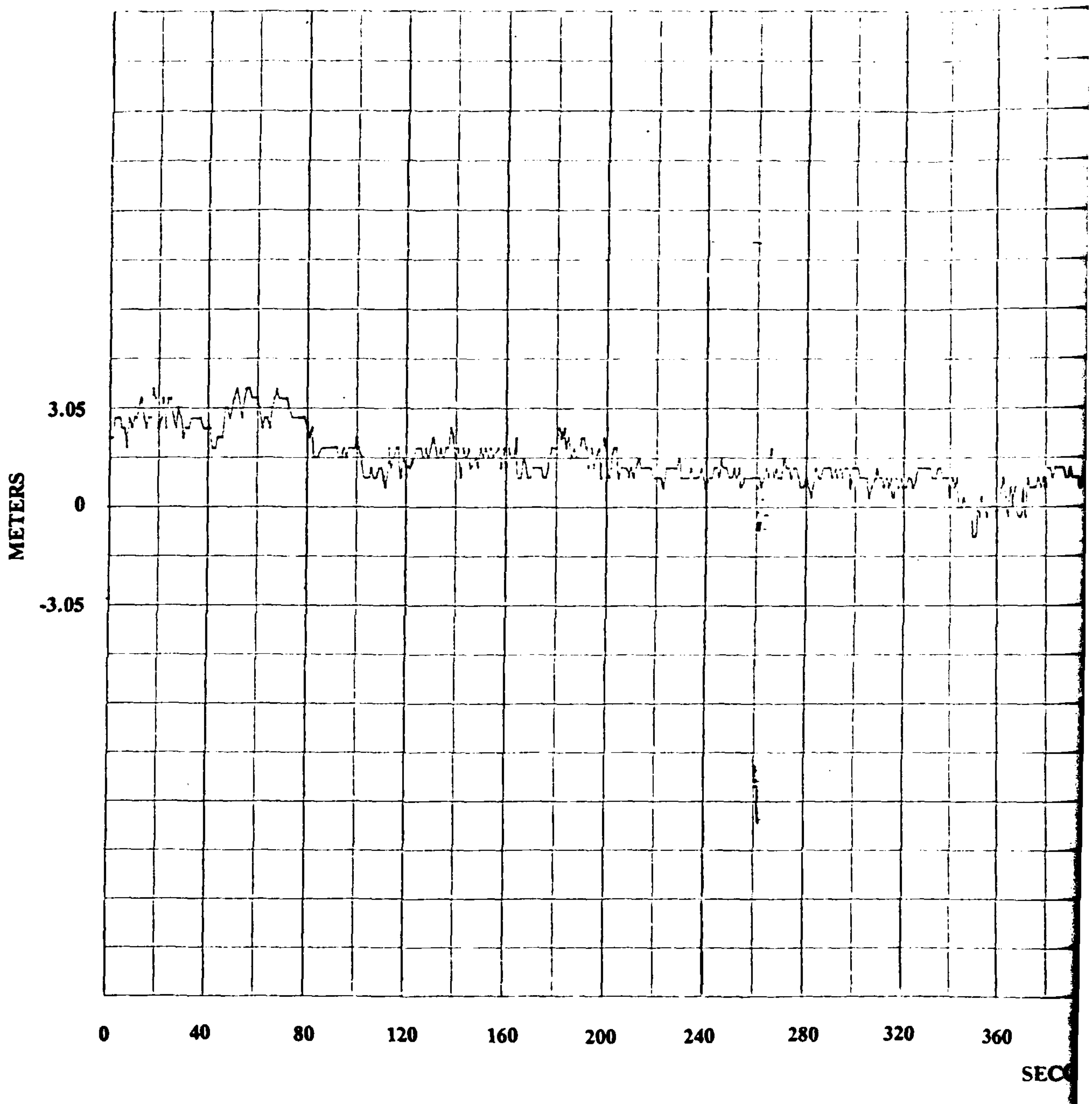
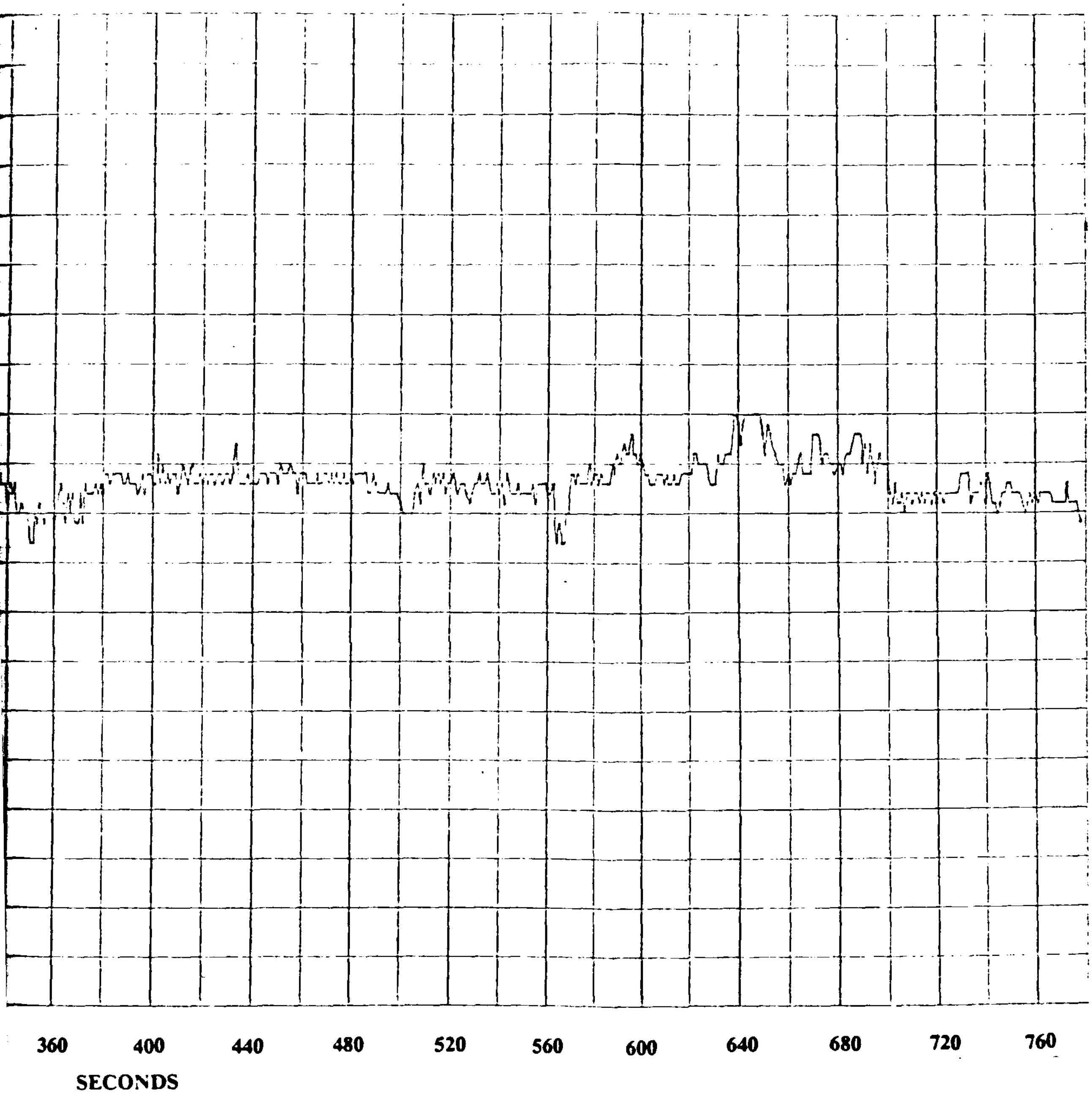


Figure 3-1. Raw



1. Raw Range Data, Segment MN

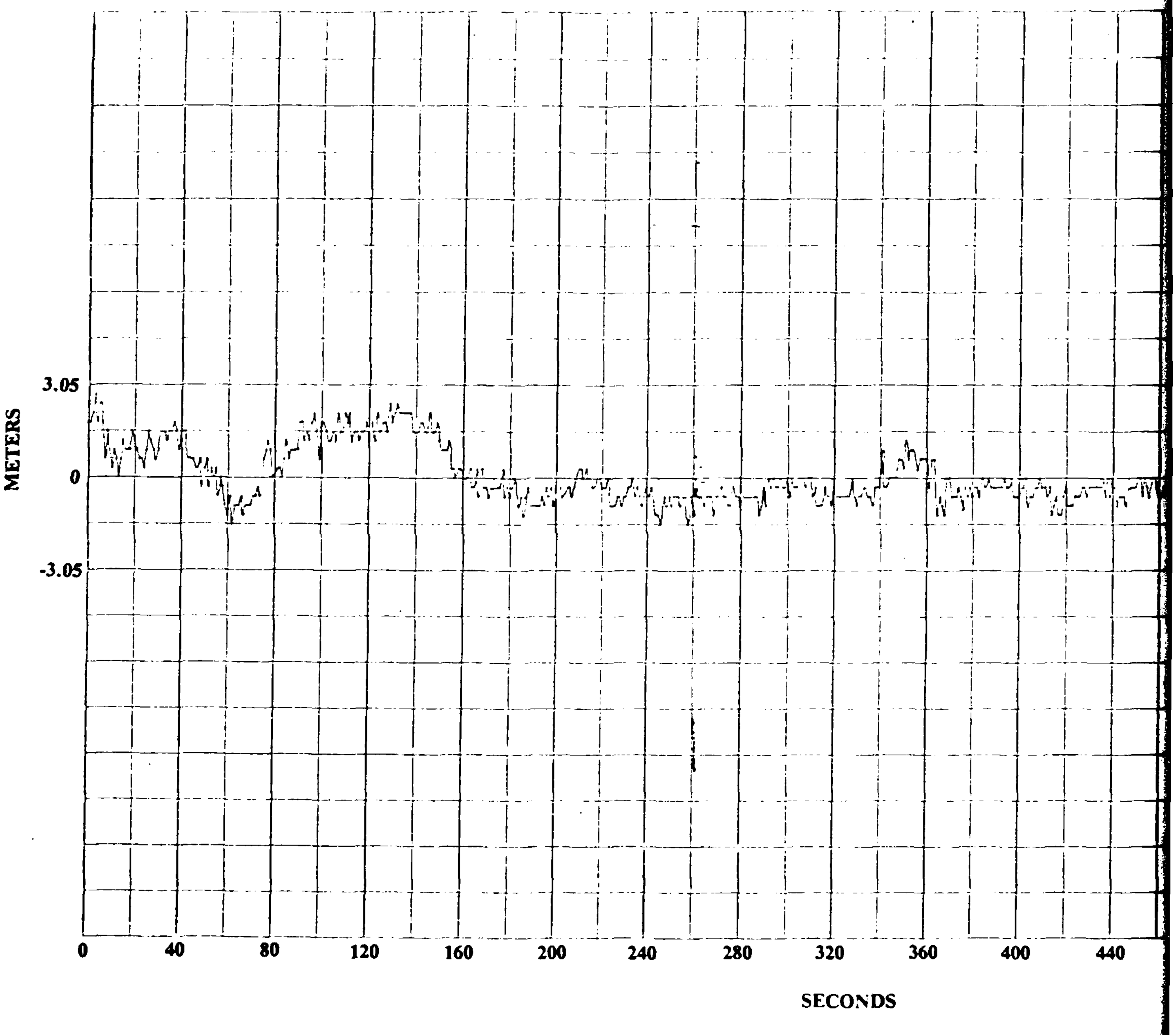
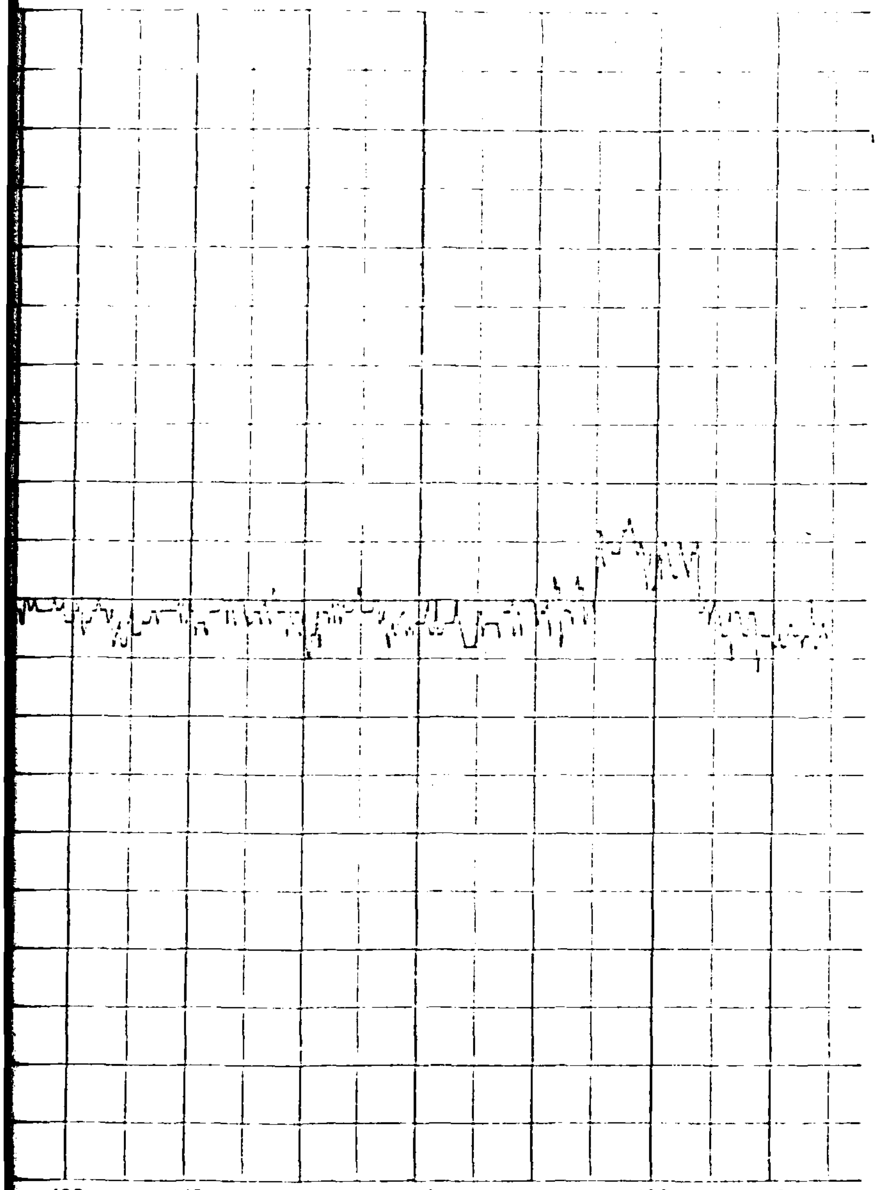


Figure 3-2. Raw Range Data, Segment BC



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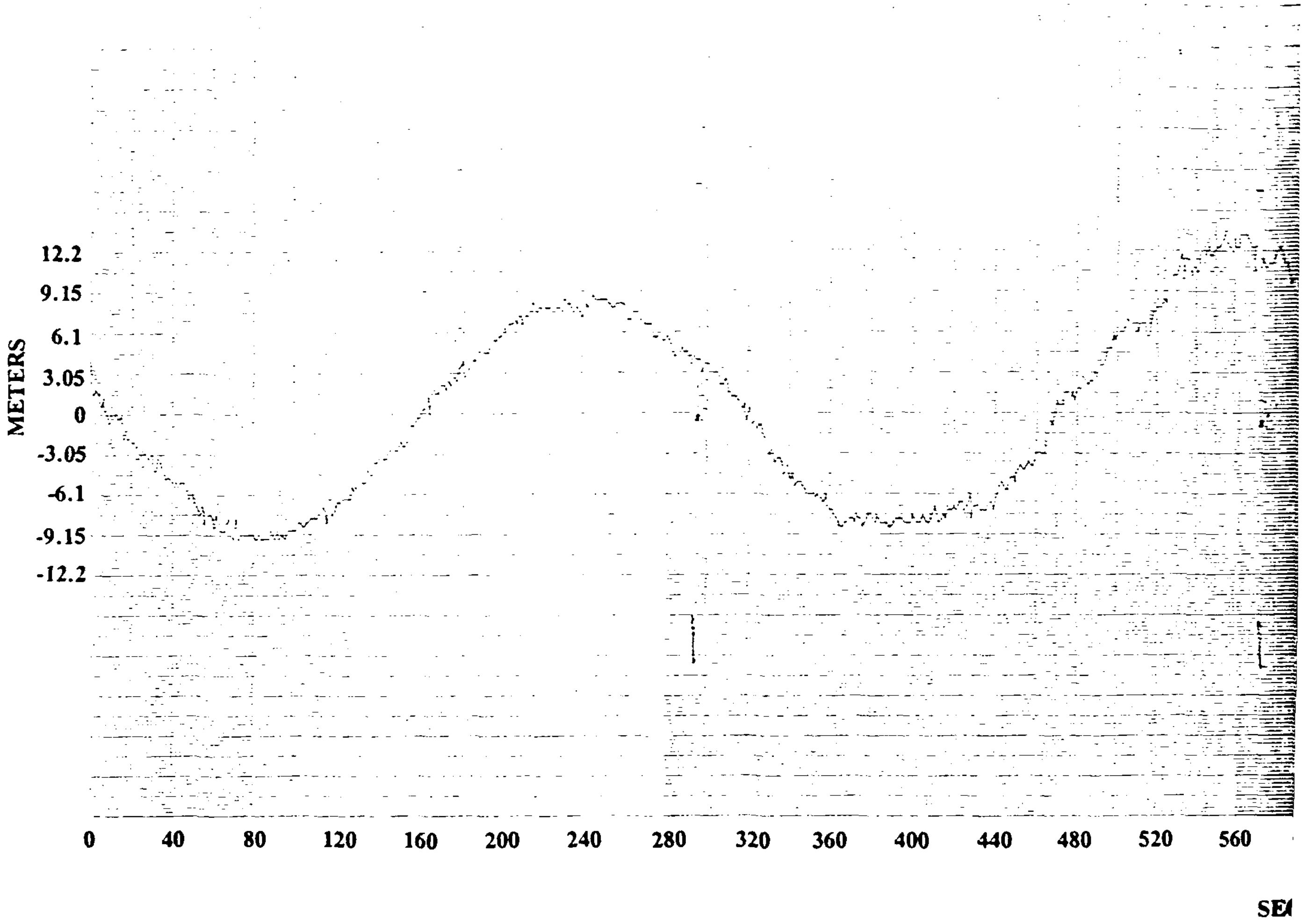
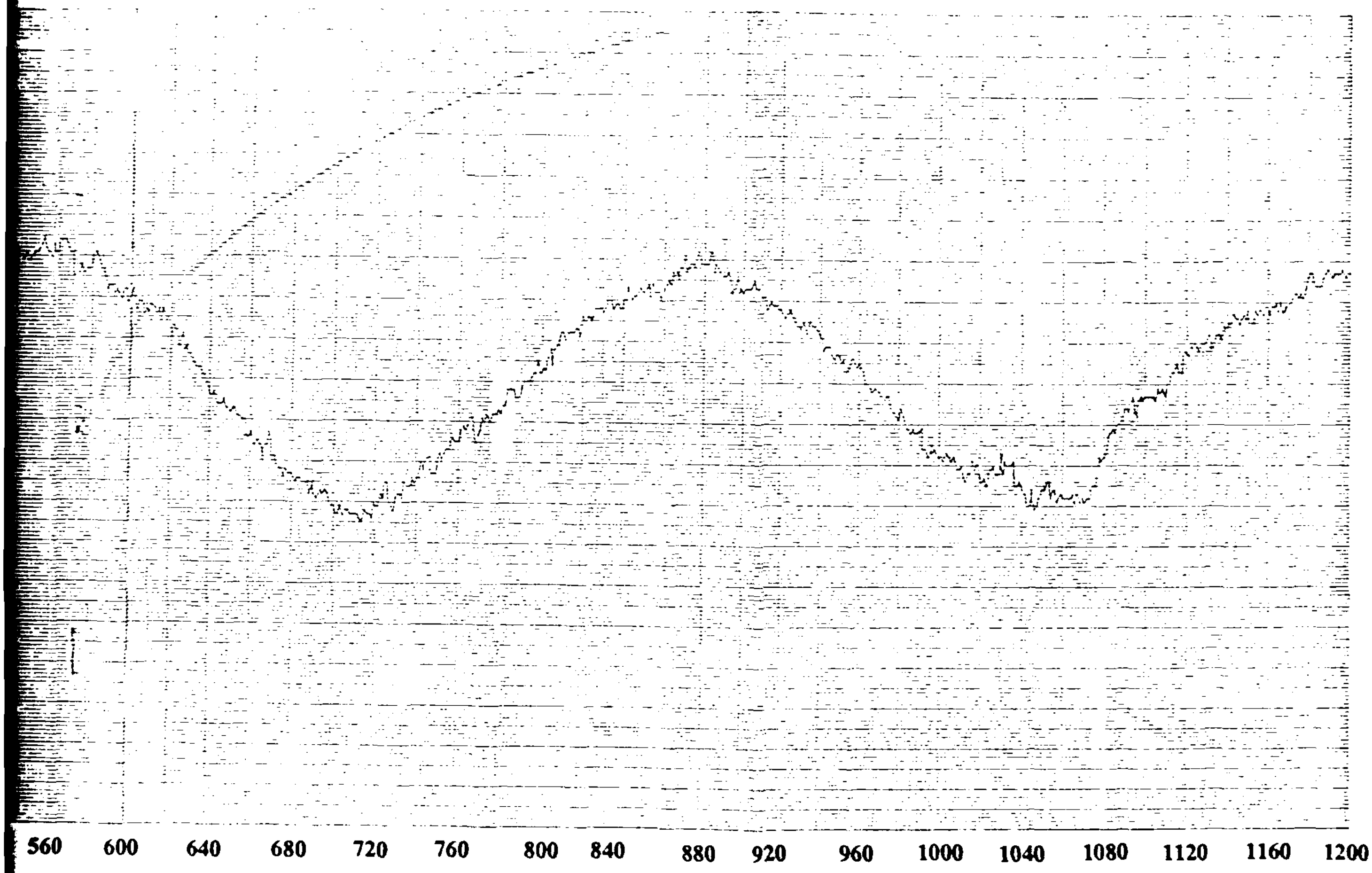
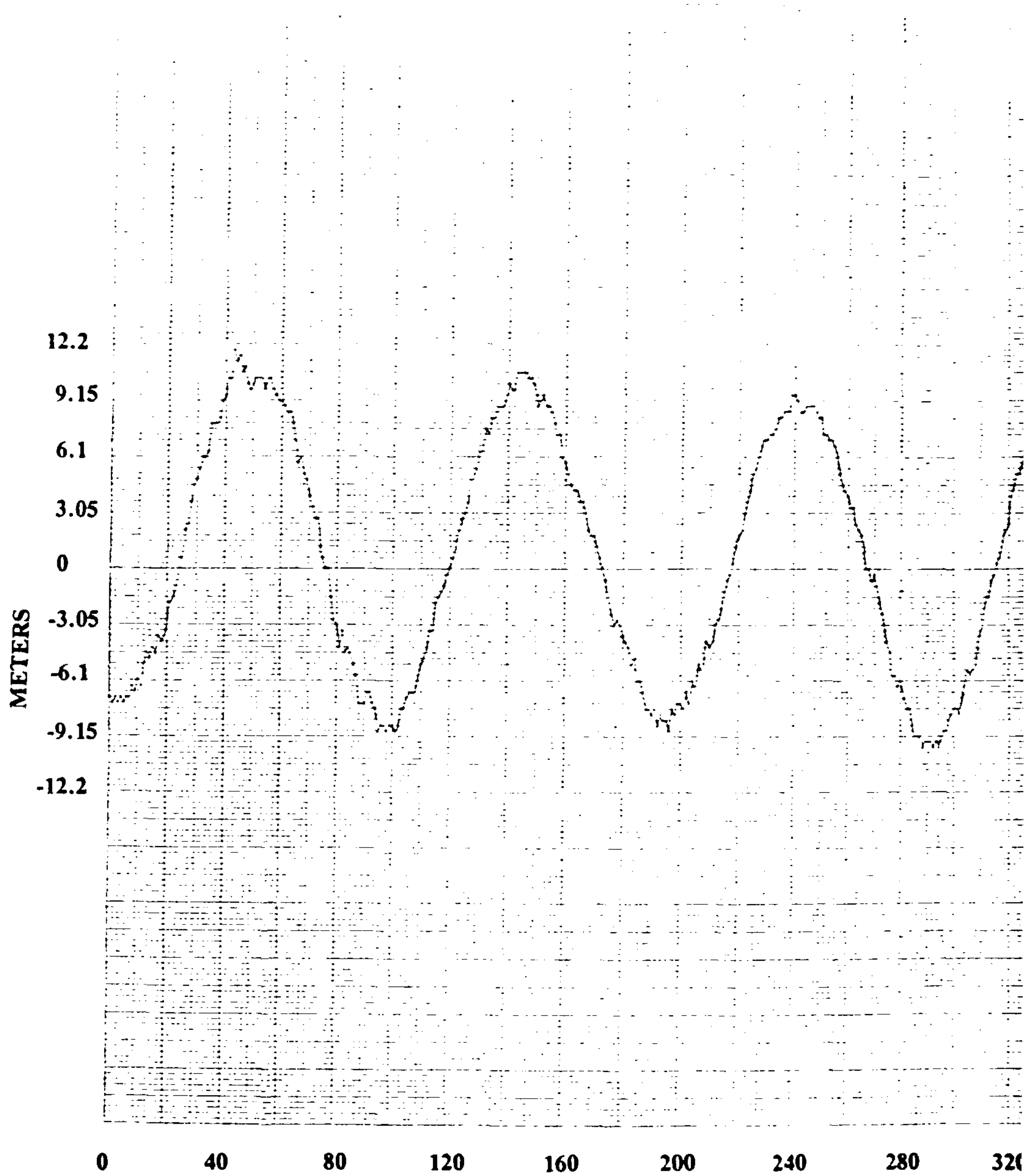


Figure 3-3. Raw Ra



Raw Range Data, Segment DE



12.2
9.15
6.1
3.05
0
-3.05
-6.1
-9.15
-12.2
METERS
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40
80
120
160
200
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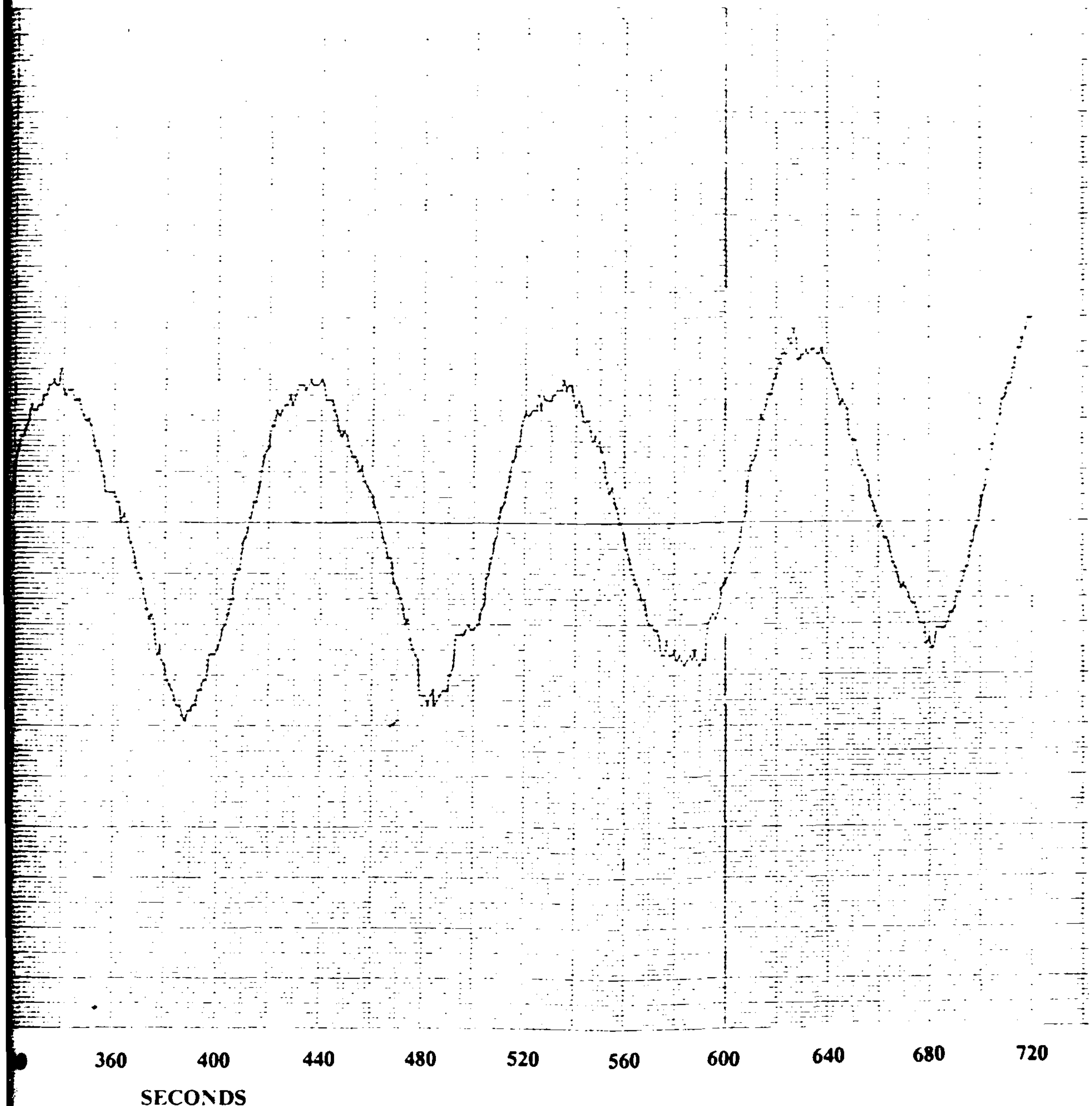
280
32(

Figure 3-4.



Raw Range Data, Segment JK

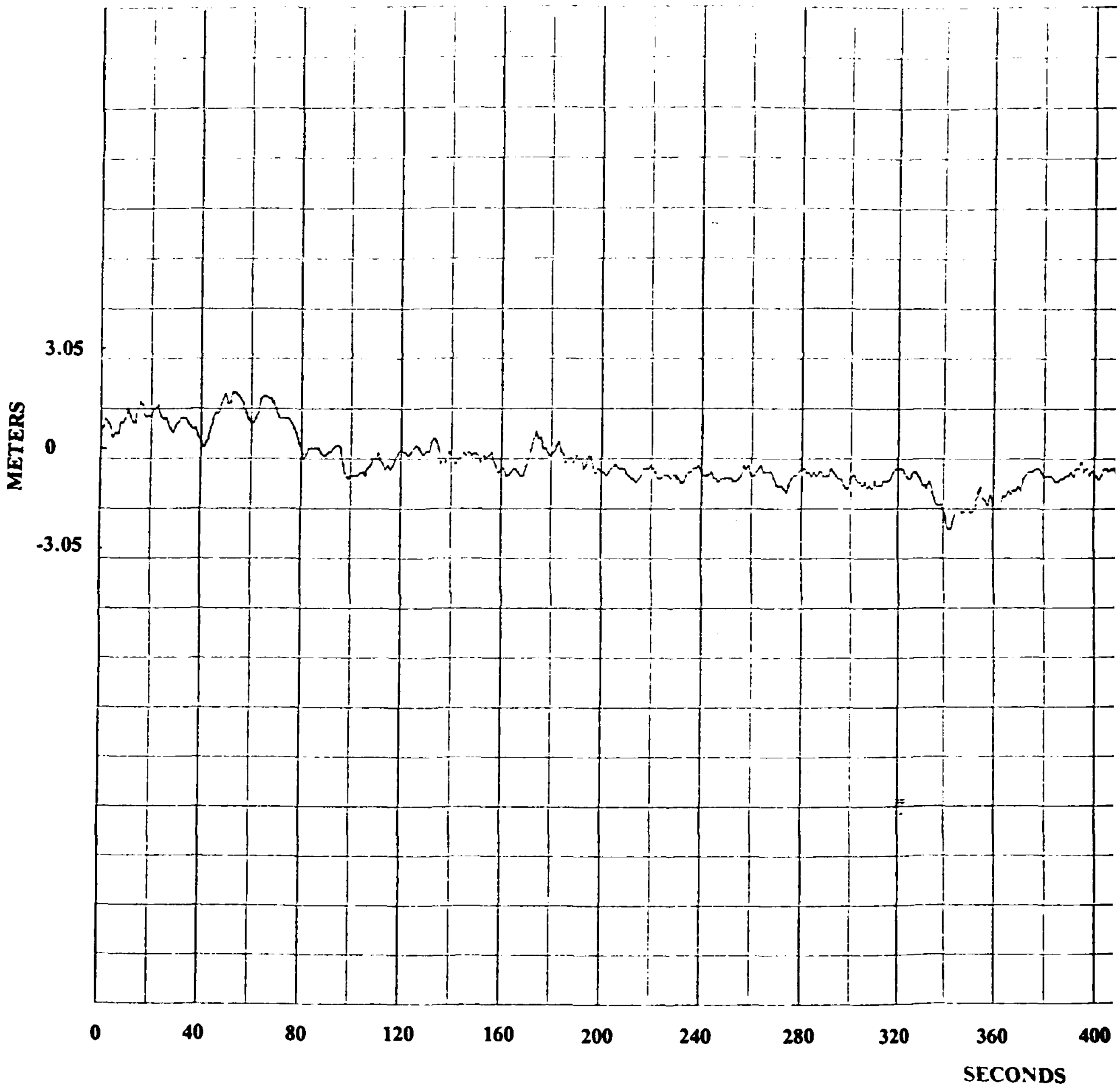


Figure 3-5. Segment MN, Range Data

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e Data With 3 Second Averaging

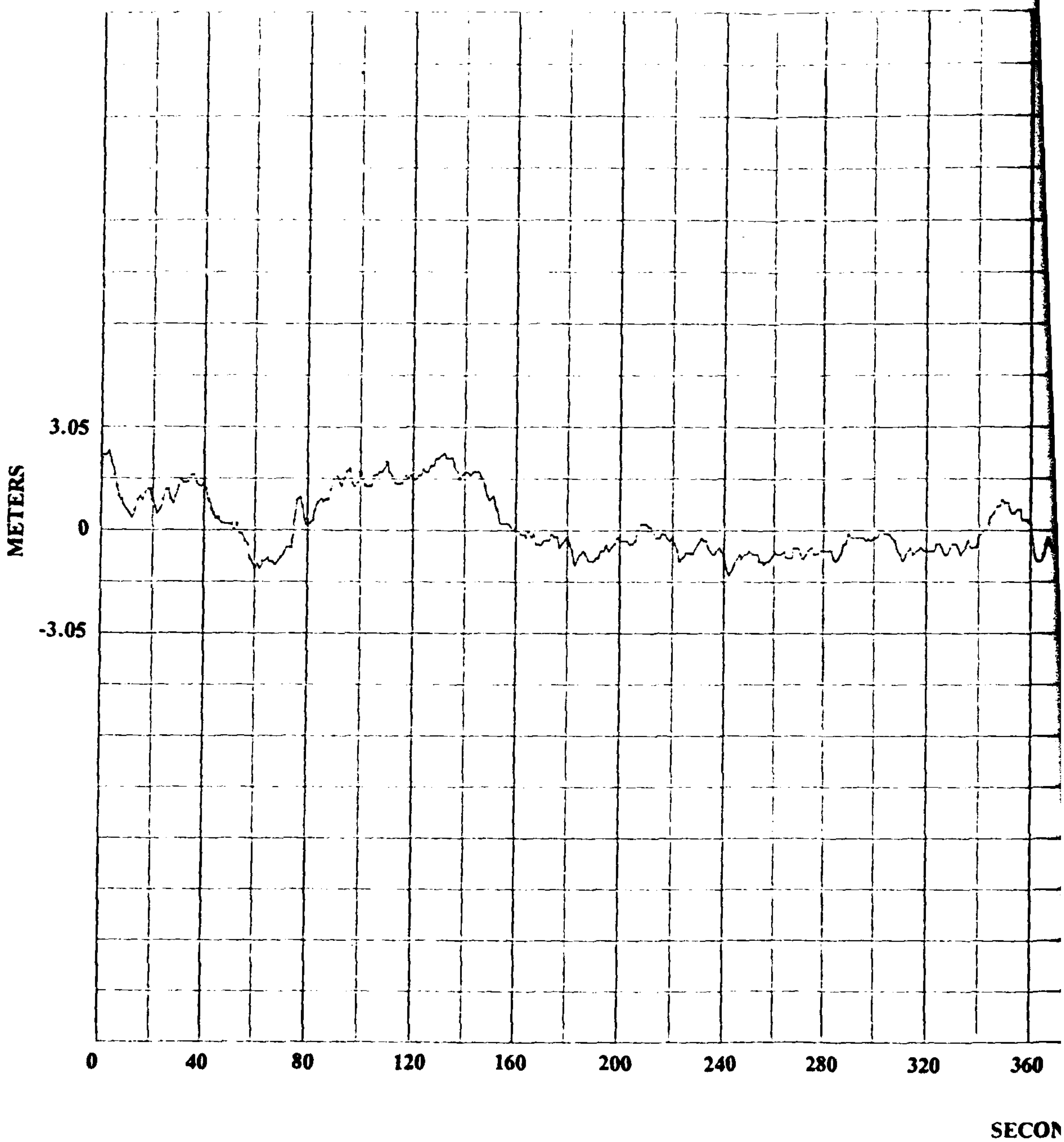
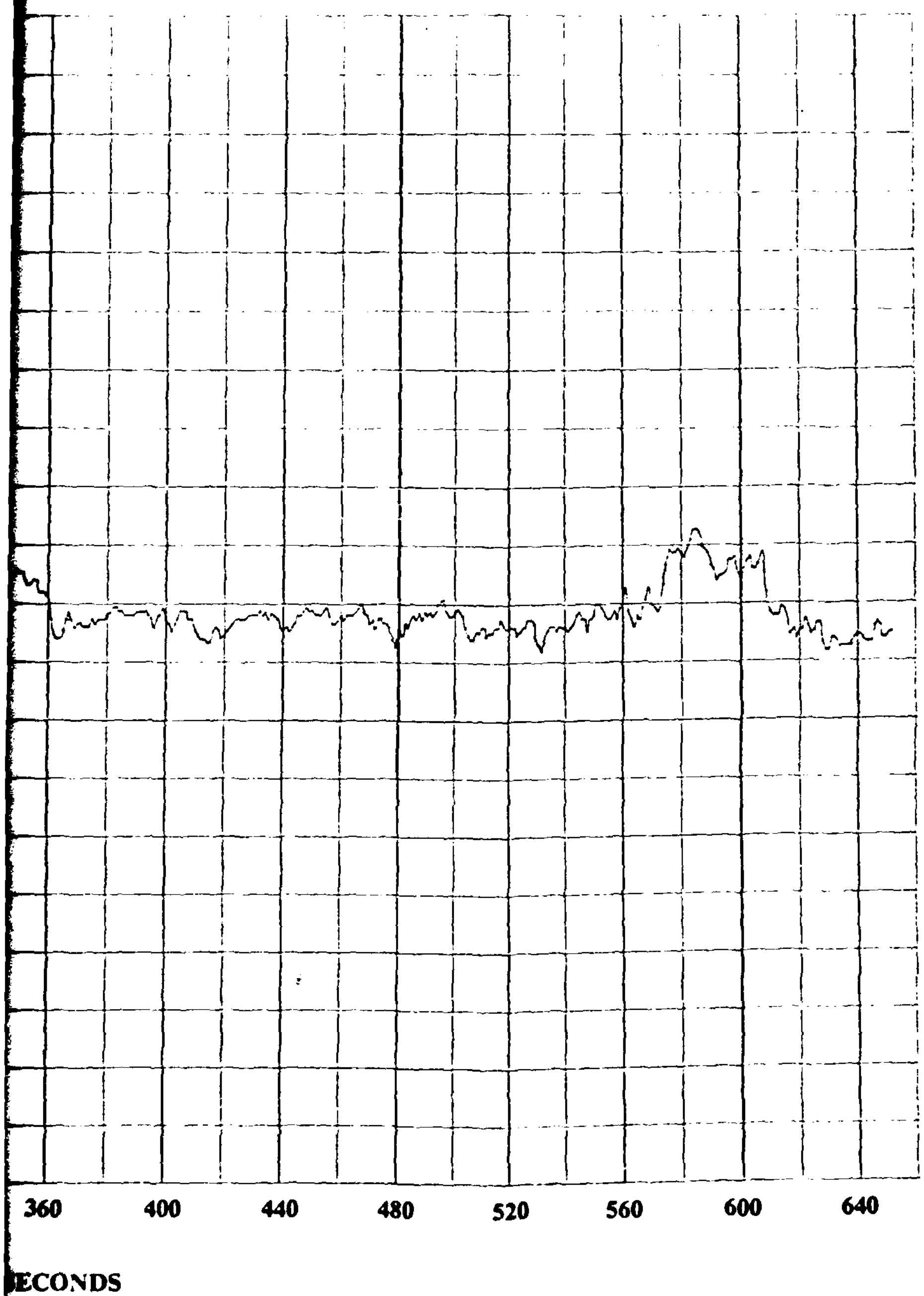


Figure 3-6. Segment BC, Range



ange Data With 3 Second Averaging

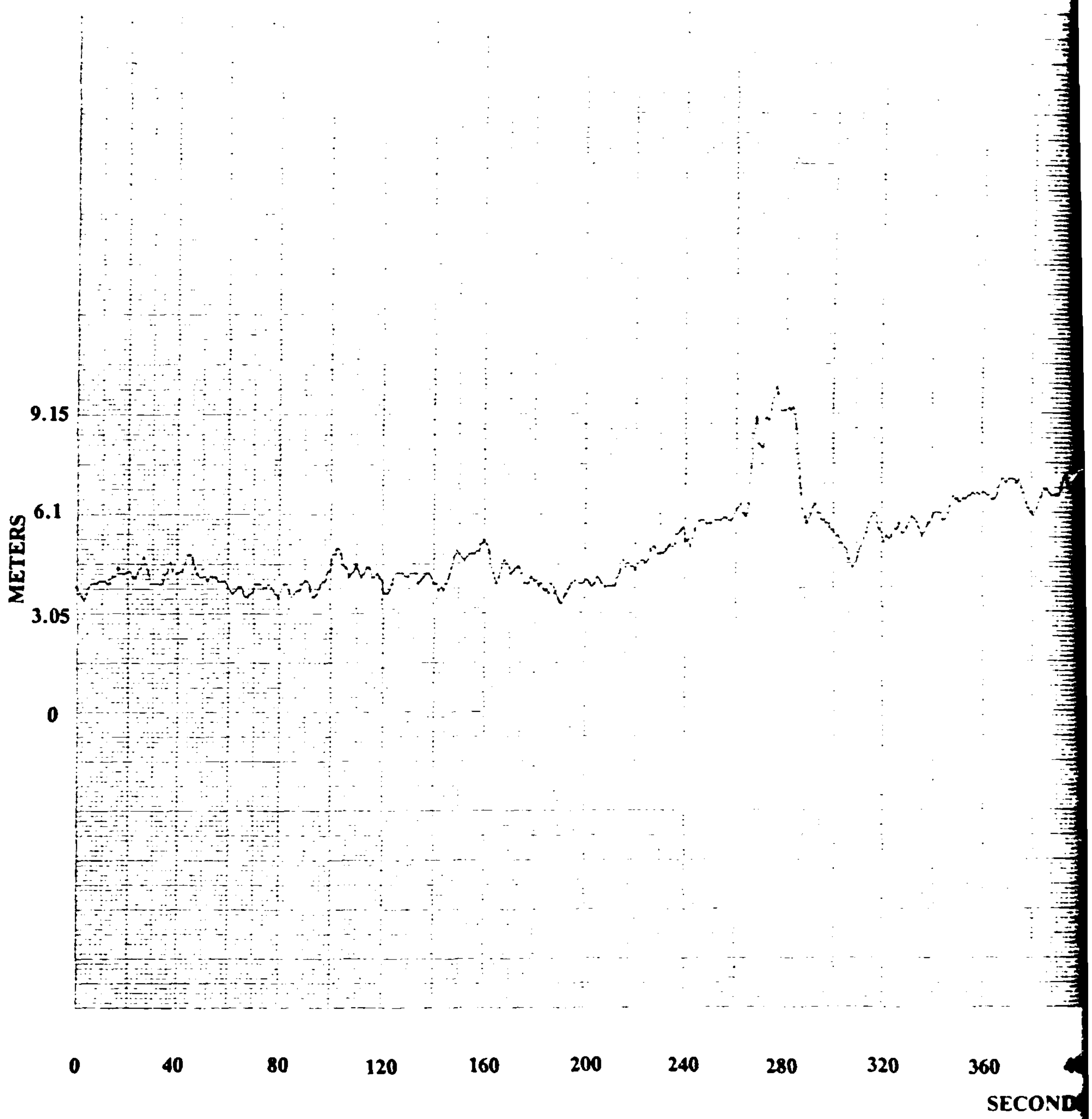
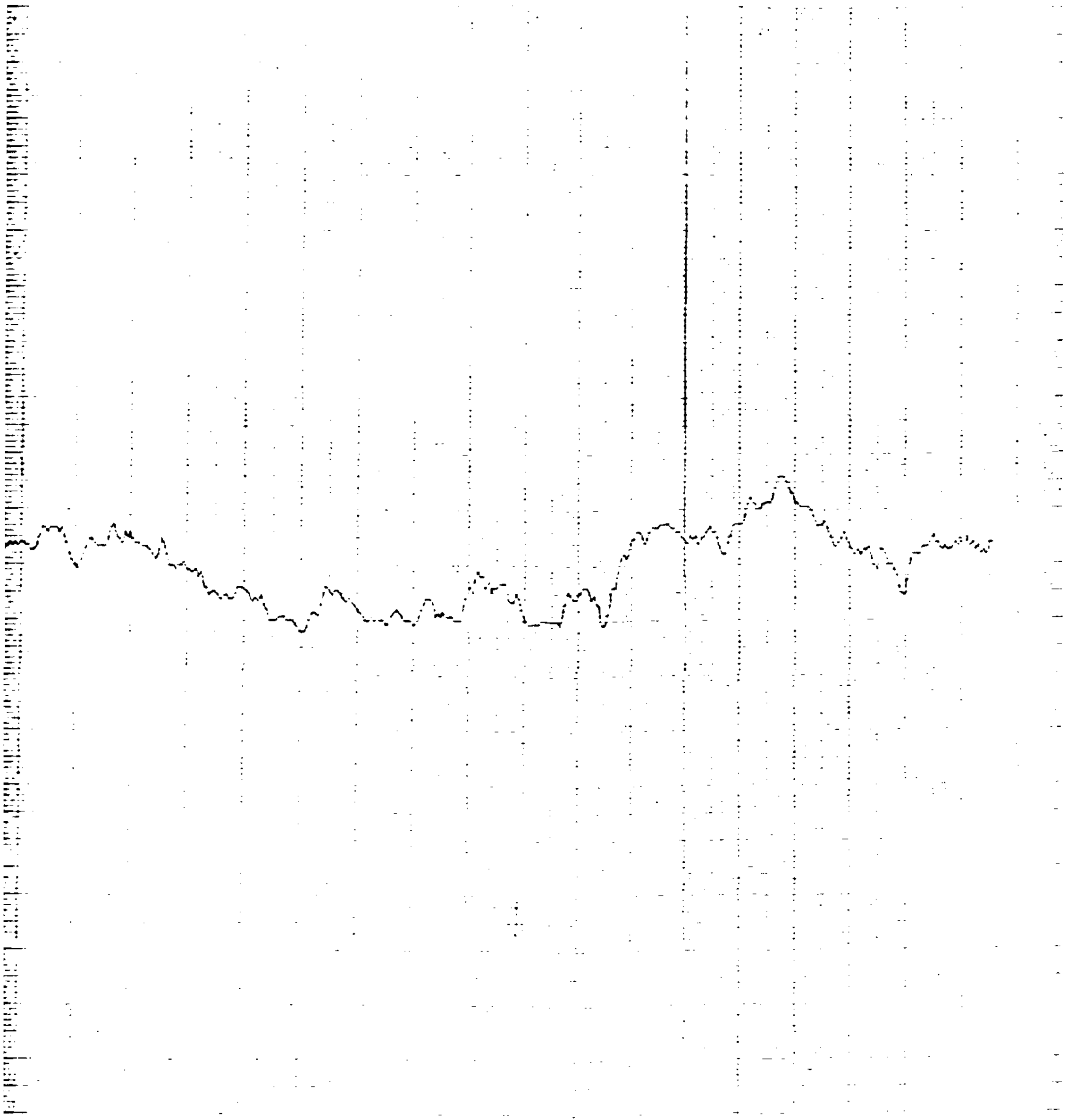


Figure 3-7. Segment NO(3) Ra



NO(3) Range Data With 3 Second Averaging

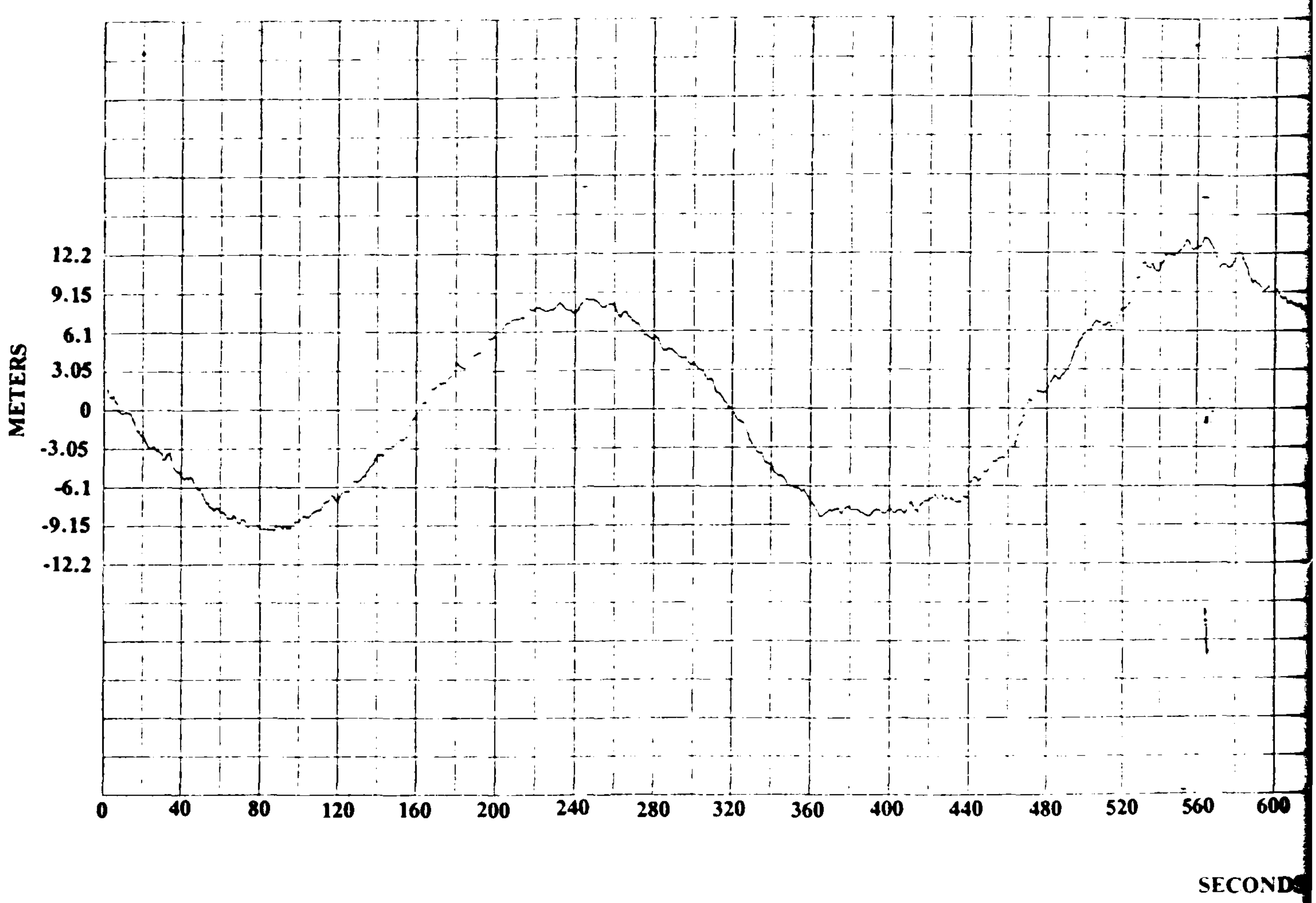
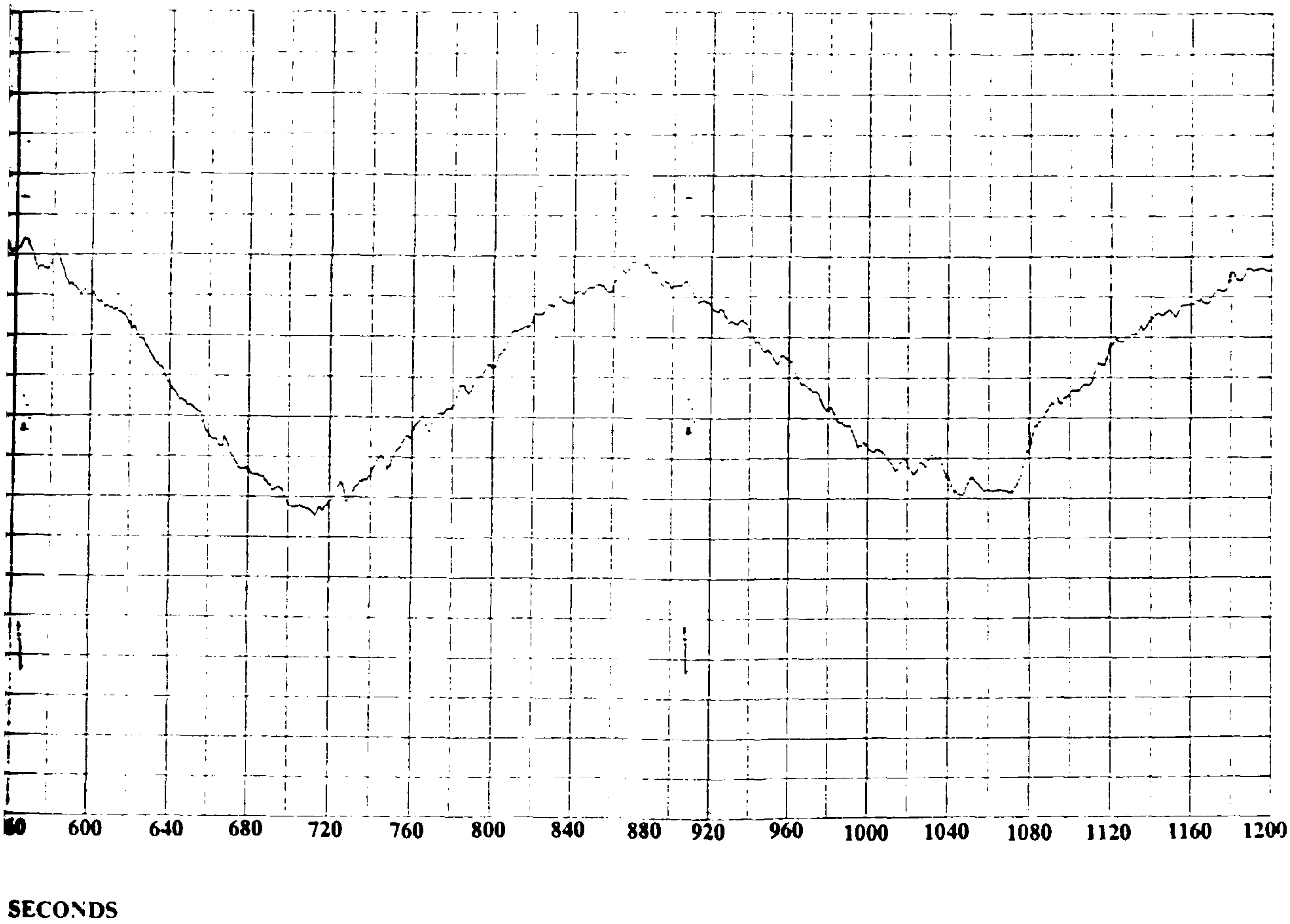


Figure 3-8. Segment DE,



nt DE, Range Data With 3 Second Averaging

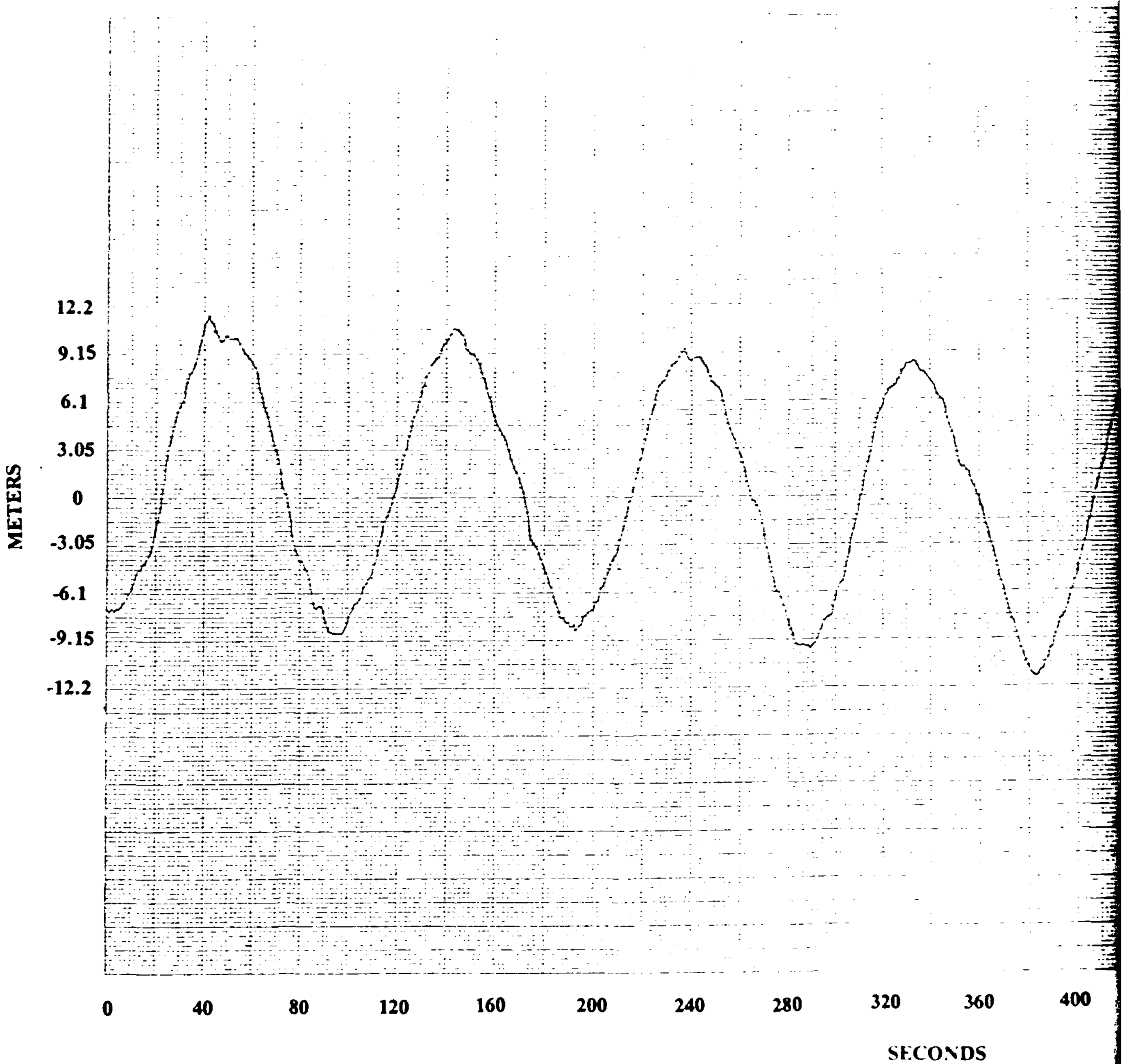
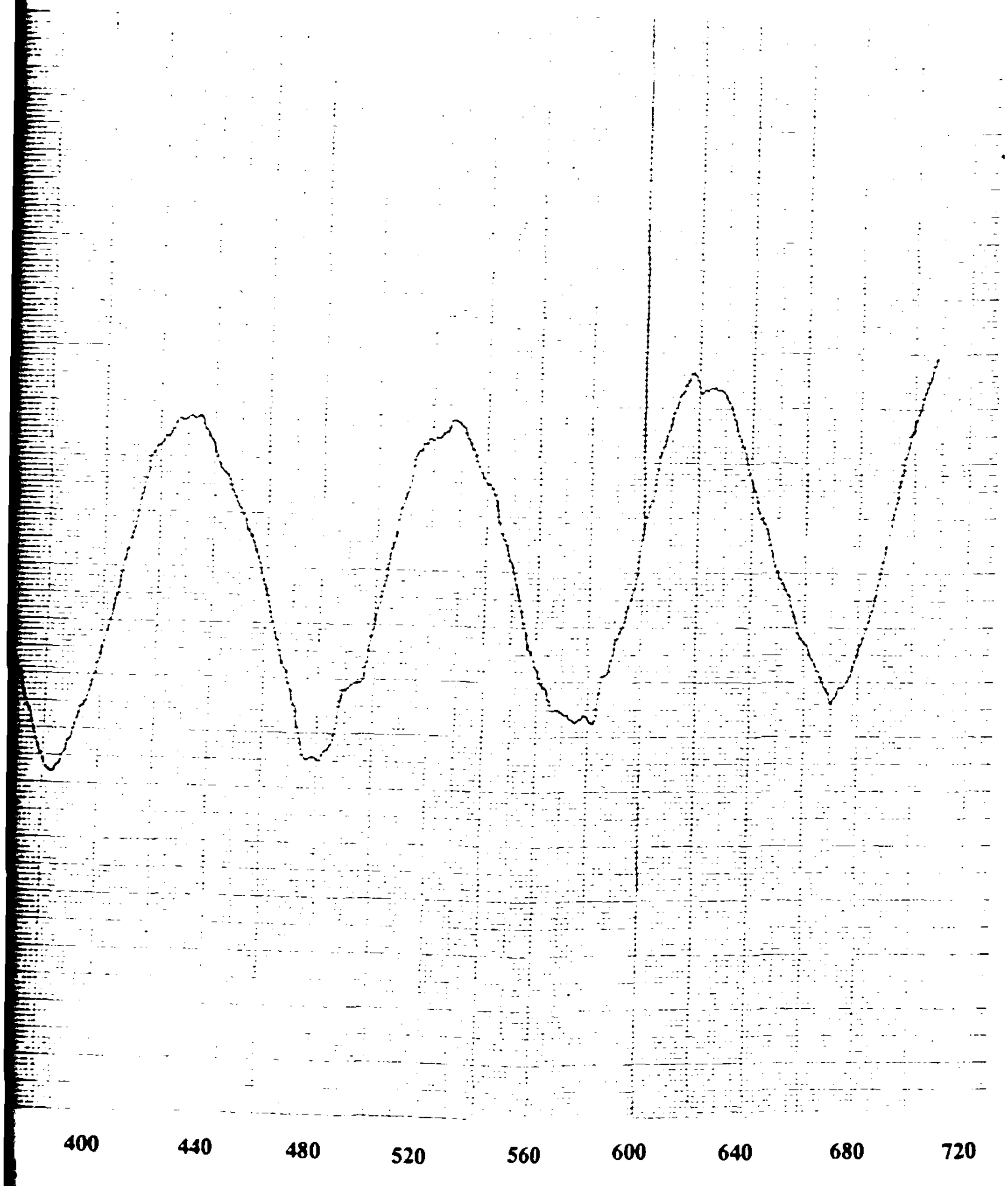


Figure 3-9. Segment JK, Range Data With 3 Second A



econd Averaging

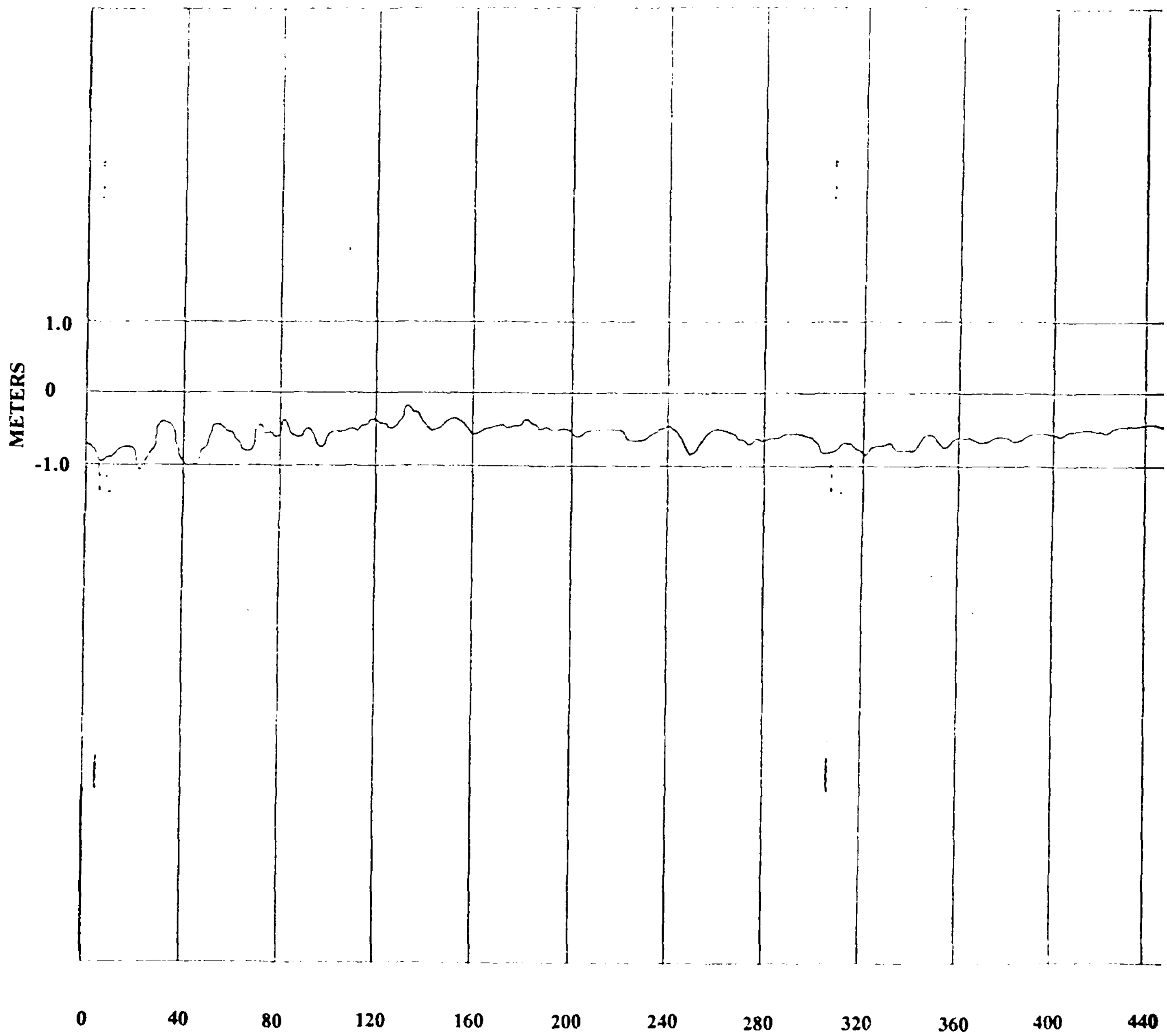
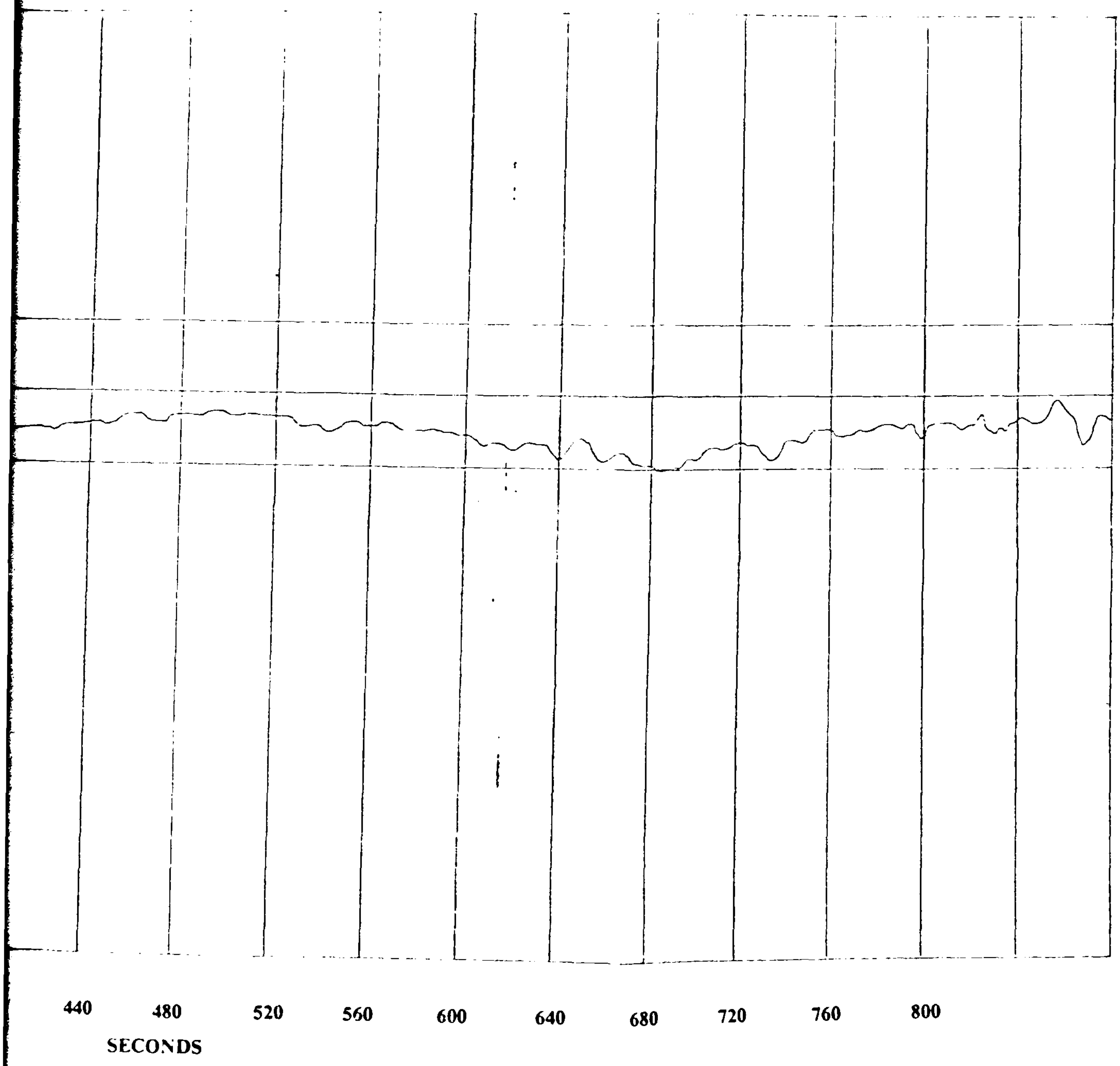


Figure 3-10. Segment M



ment MN Δ Depth Data

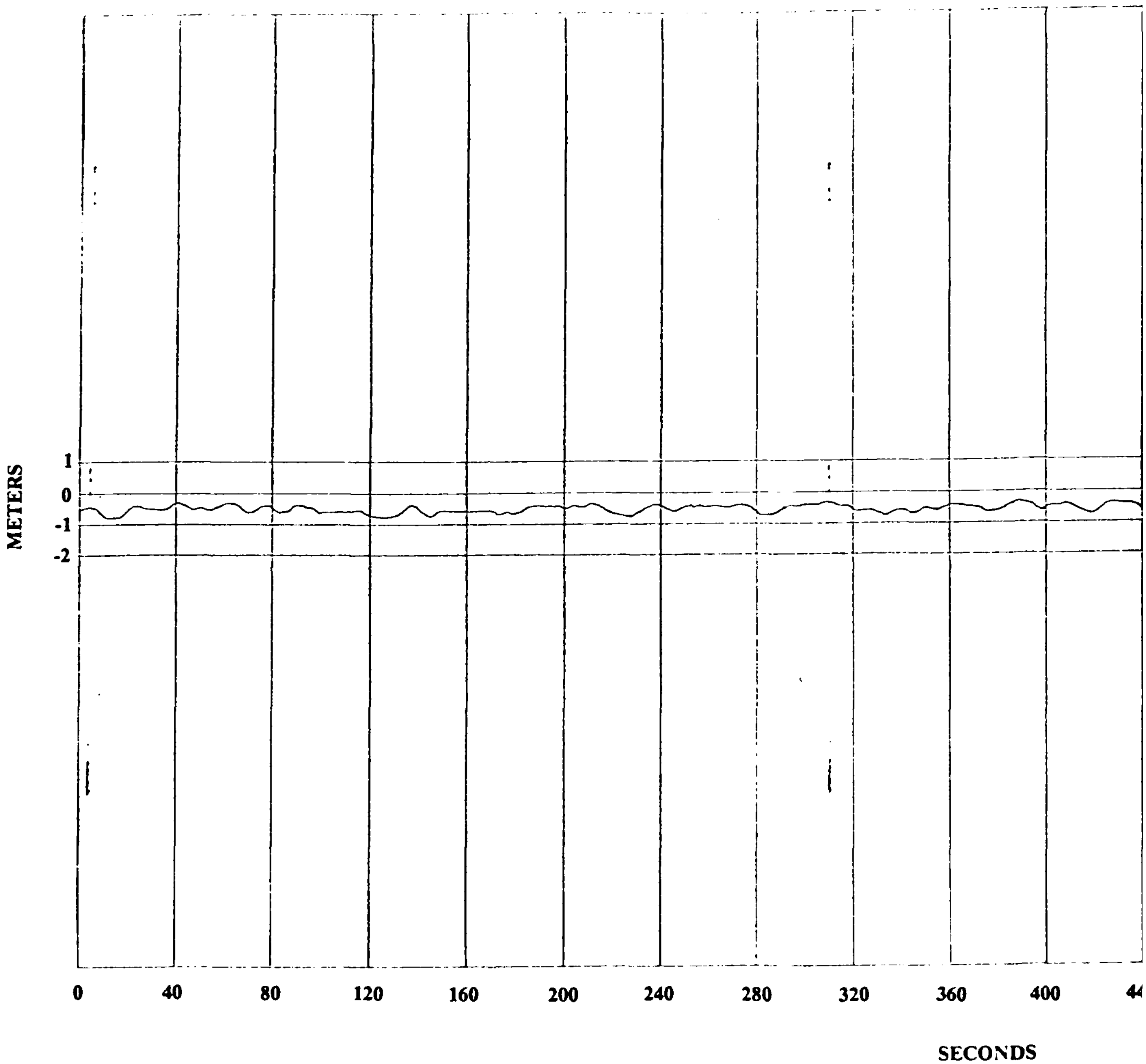
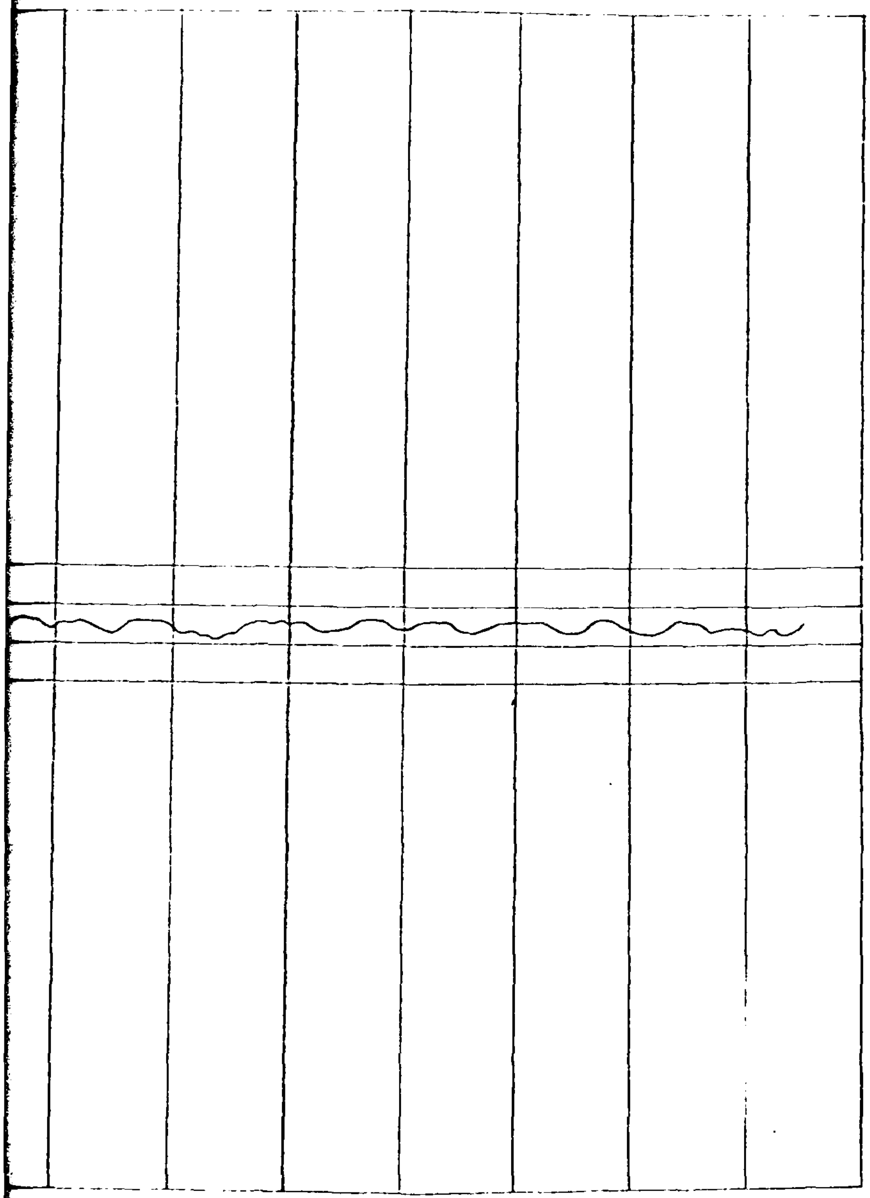


Figure 3-11. Segment BC Δ Depth Data



ps

pth Data

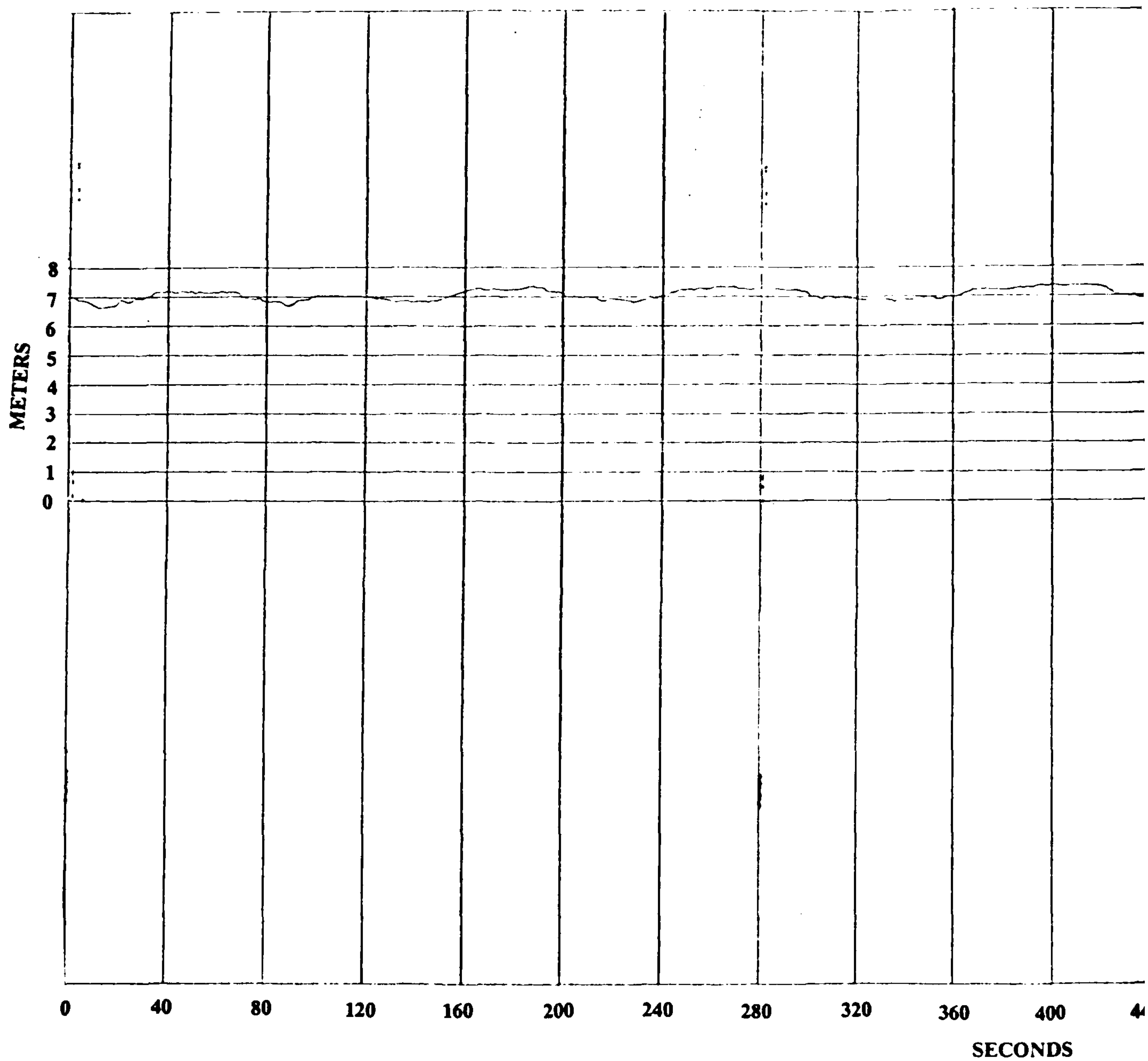
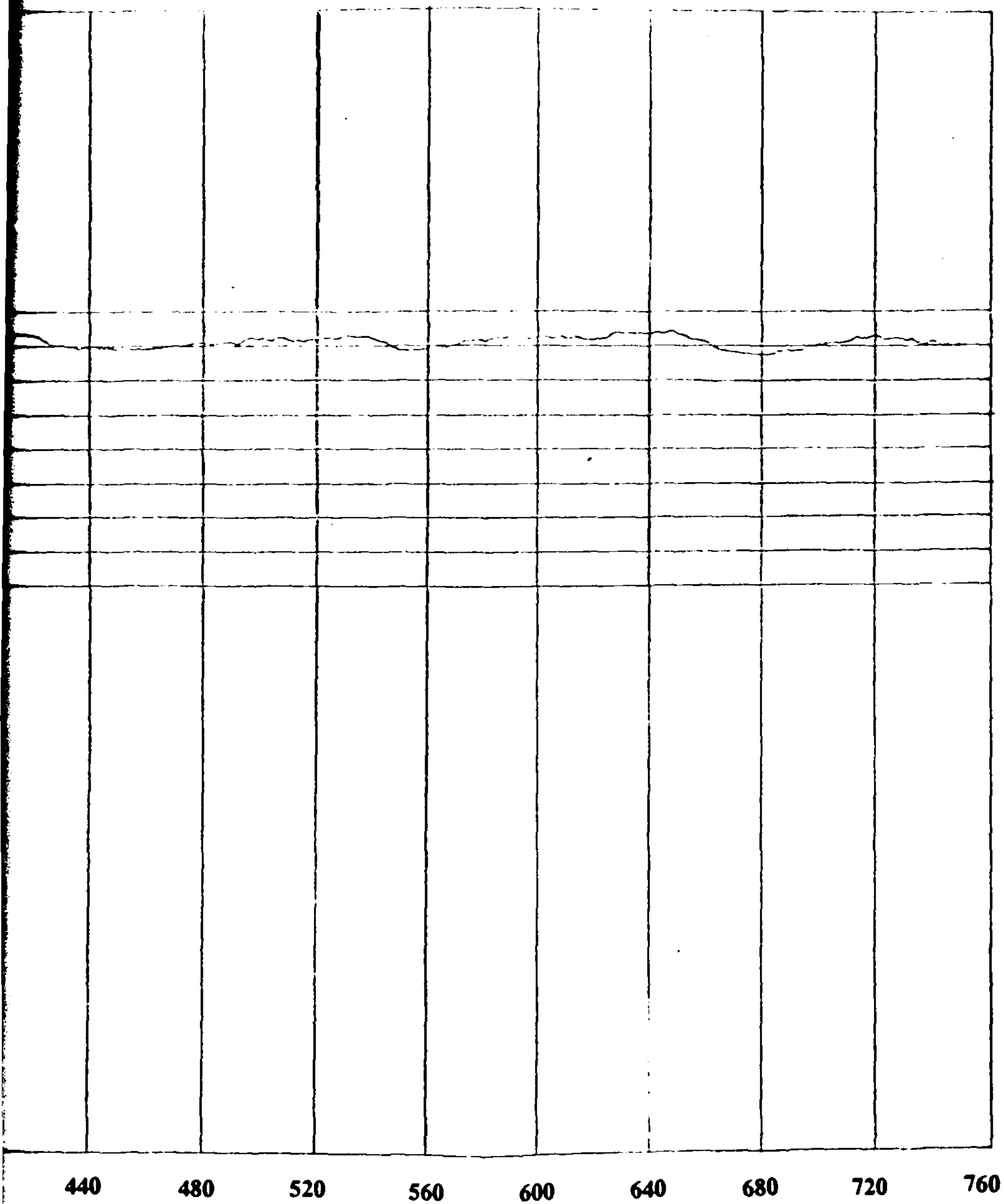


Figure 3-12. Segment NO(3)Δ D



(3)Δ Depth Data

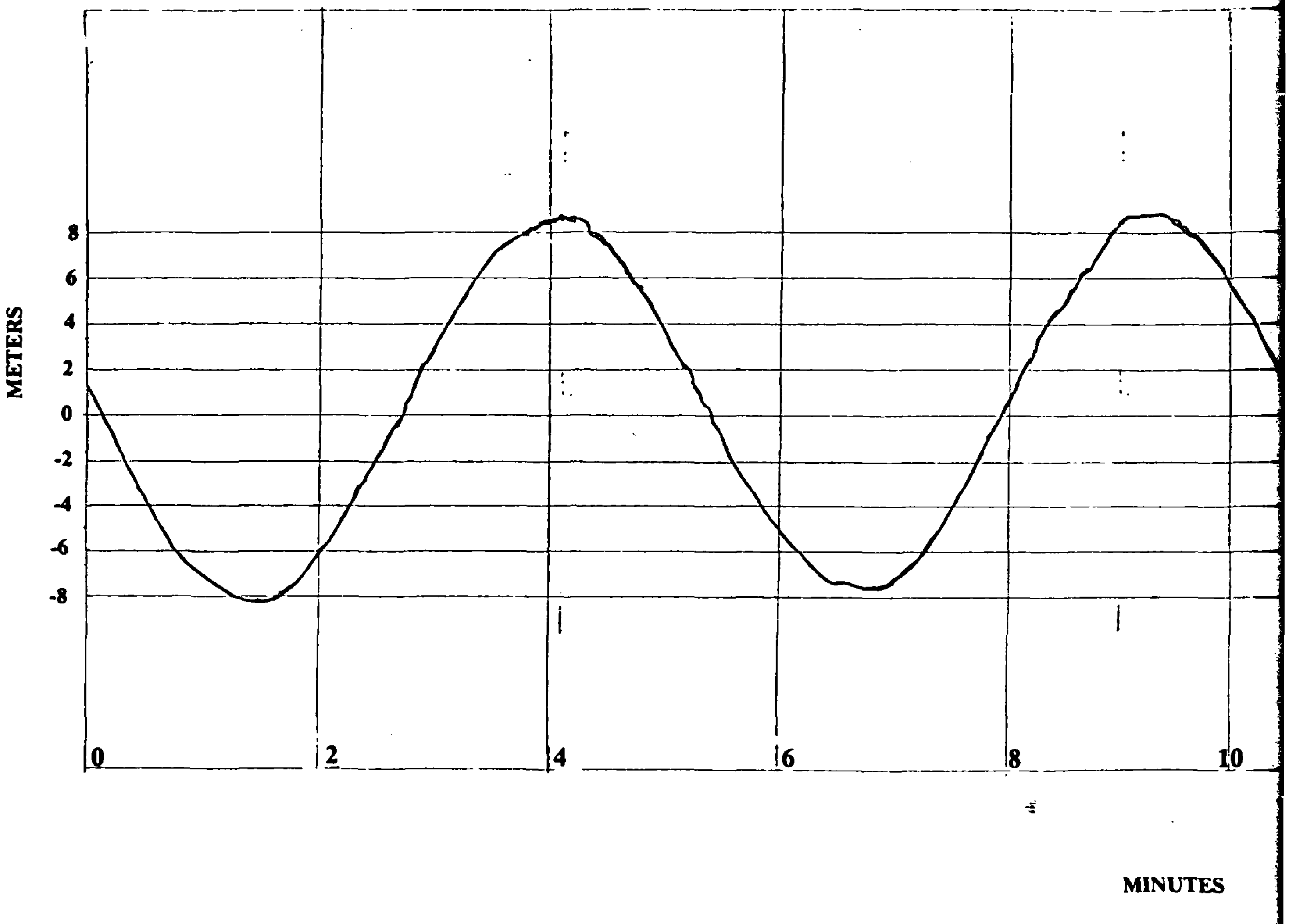
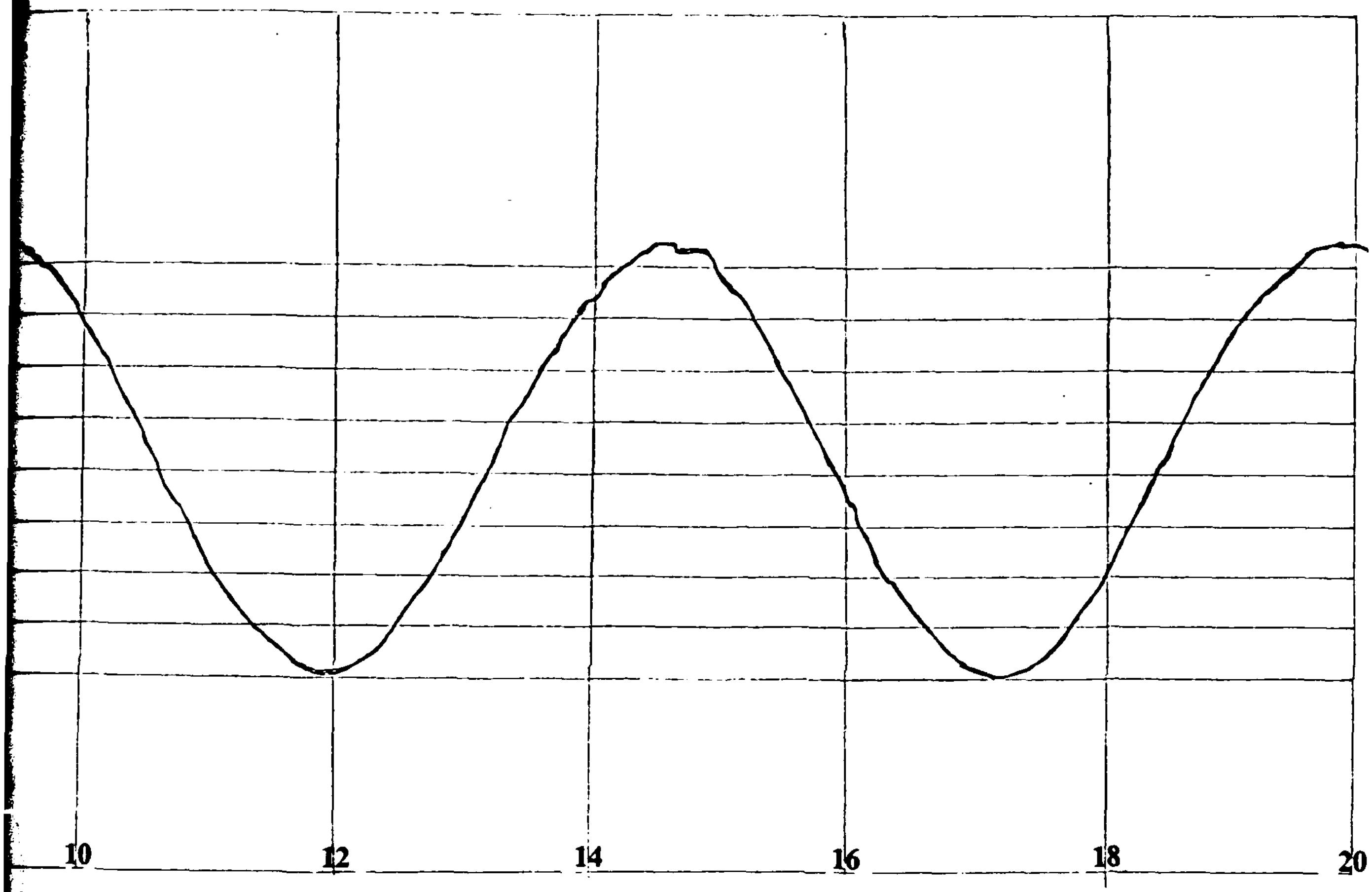


Figure 3-13. Segment DE



UTES

ent DE Δ Depth Data

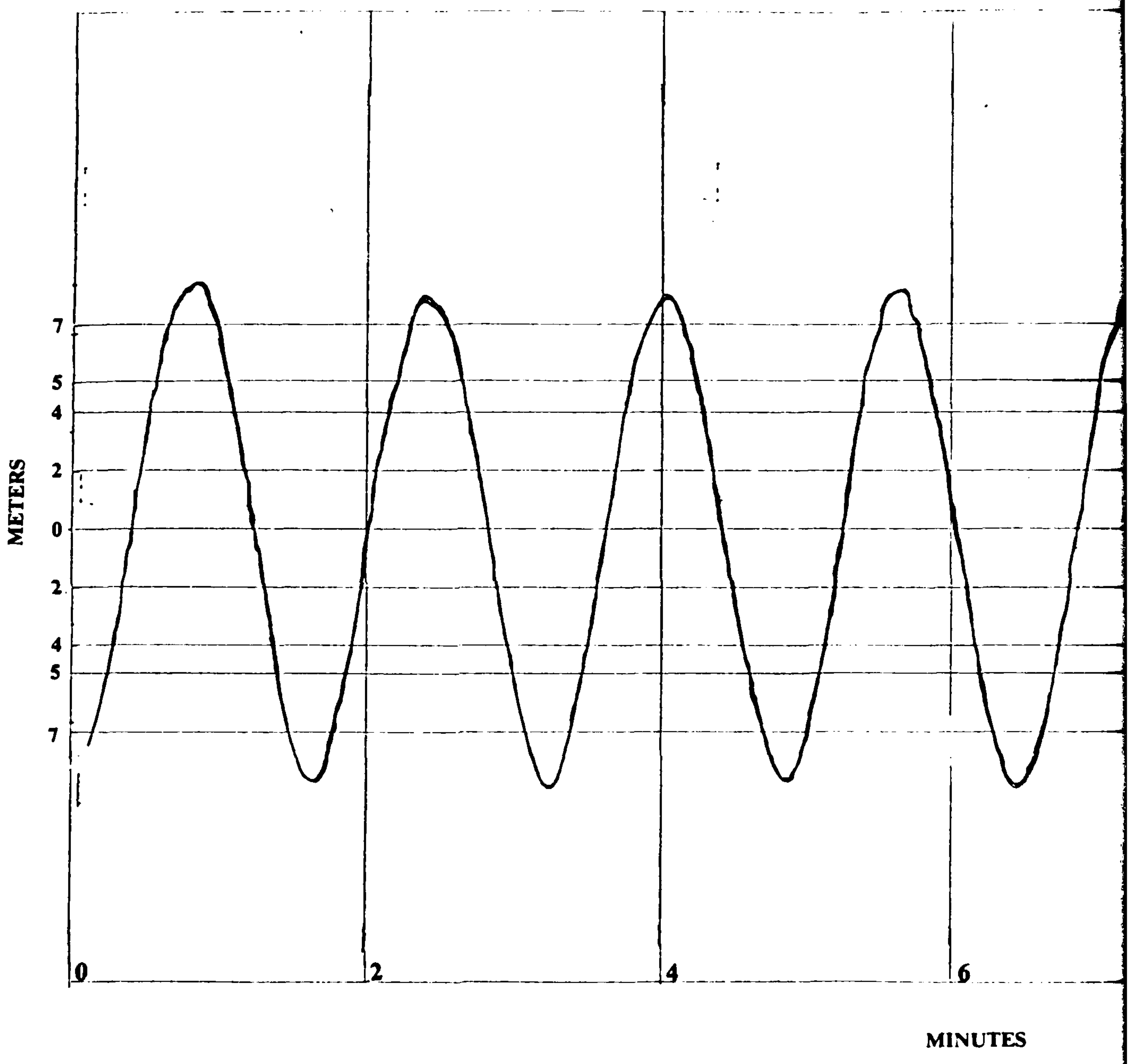
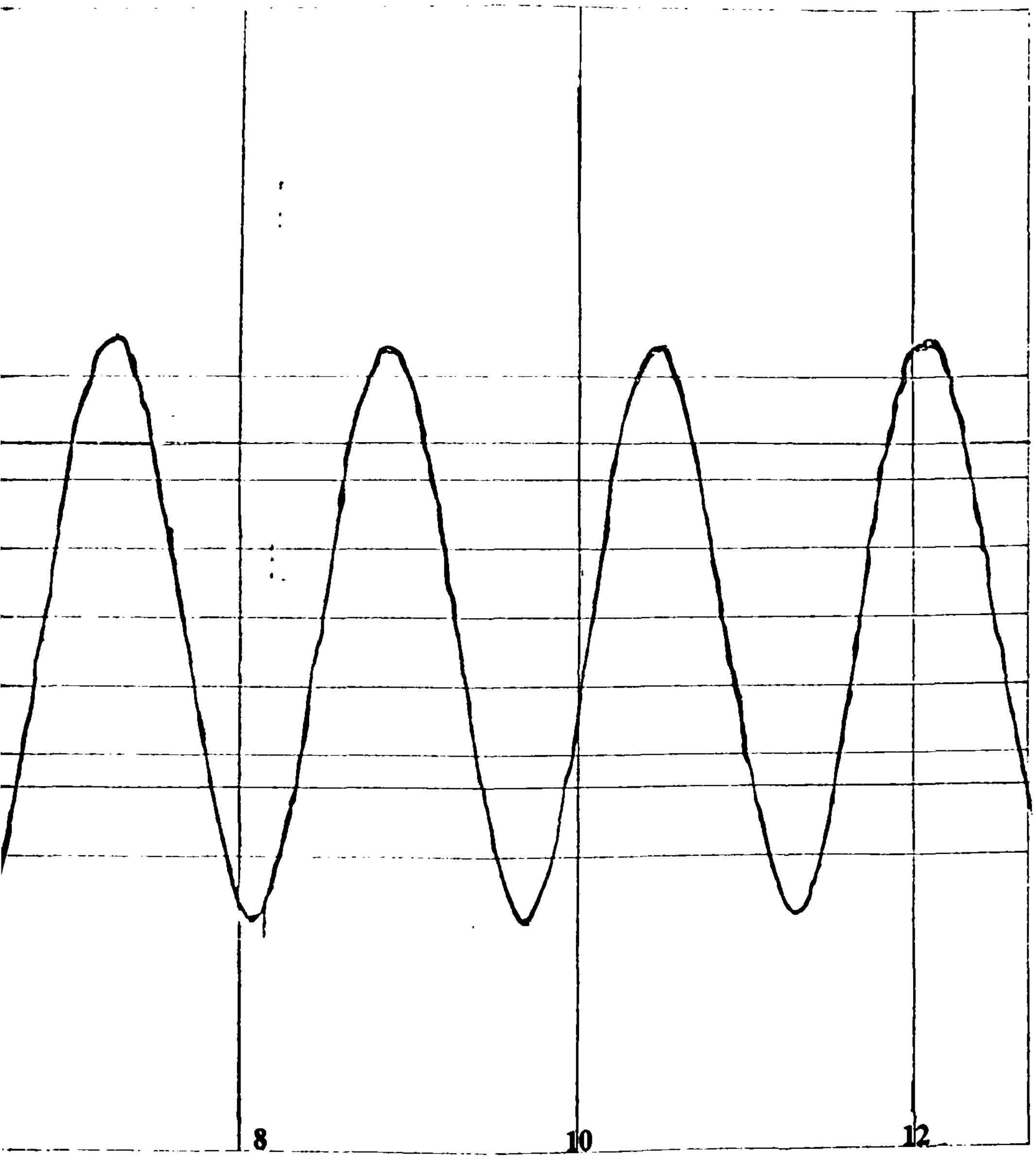


Figure 3-14. Segment JK Δ Depth Da



pth Data

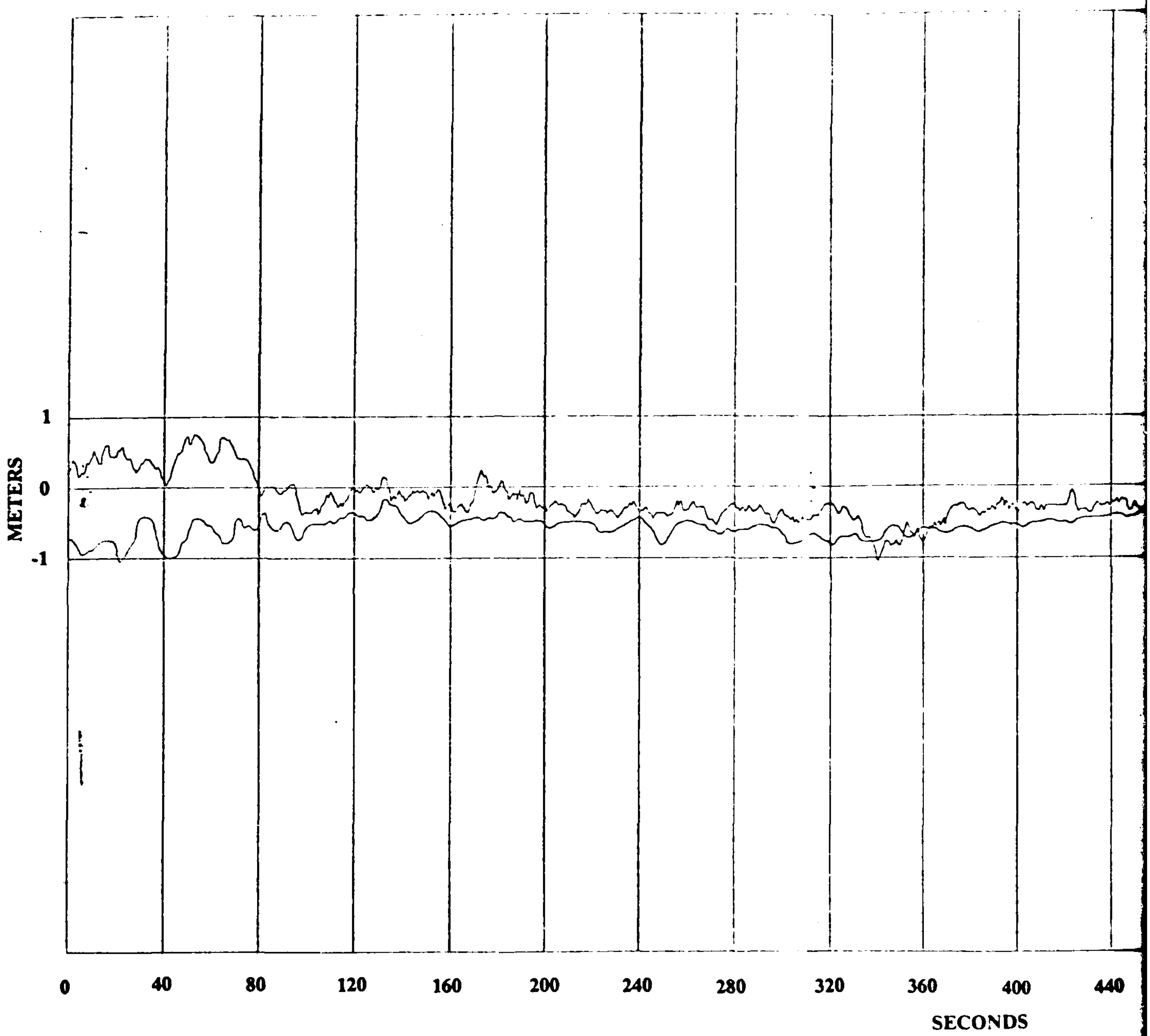
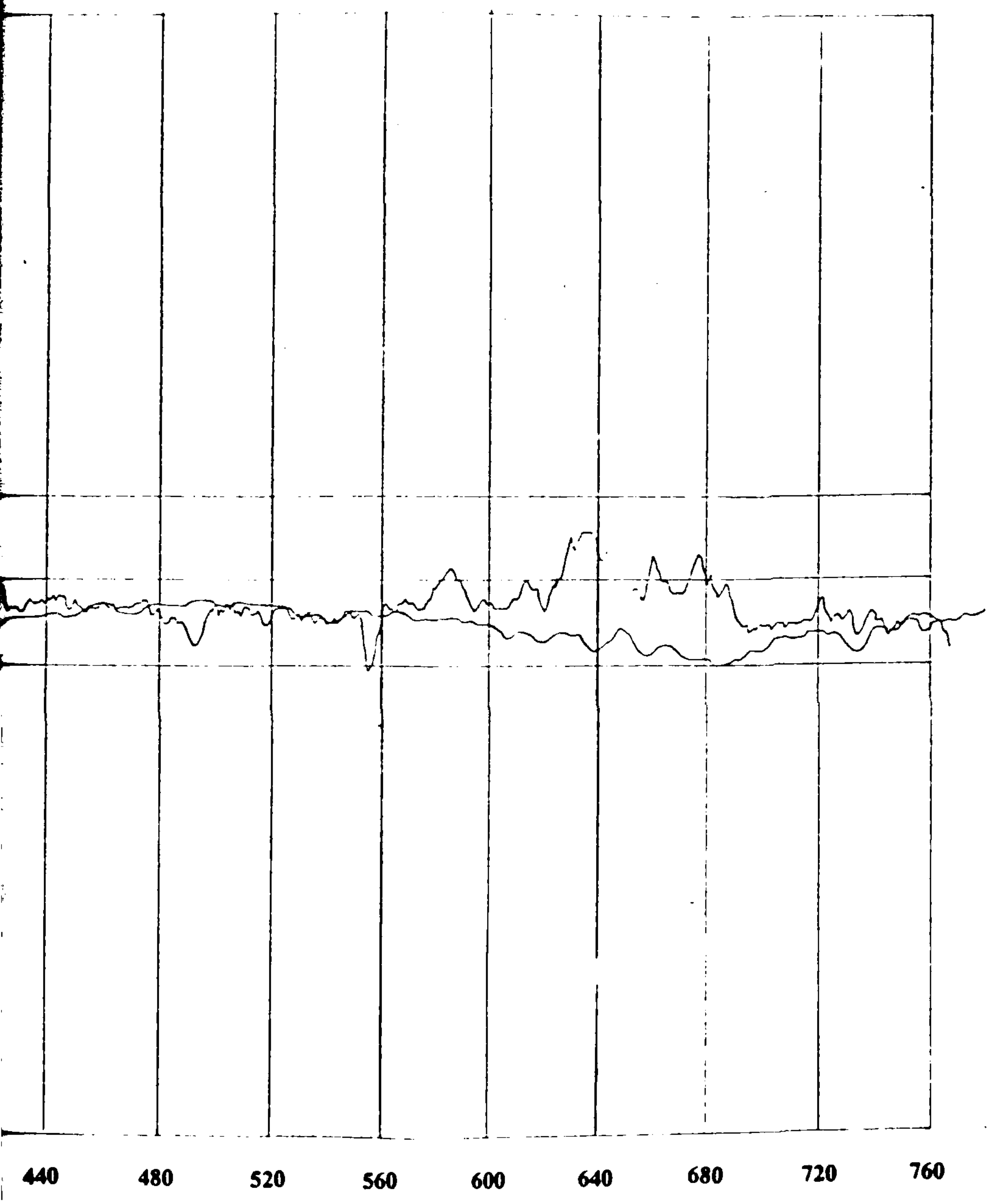


Figure 3-15. Segment MN Range and ΔD



nd Δ Depth Data

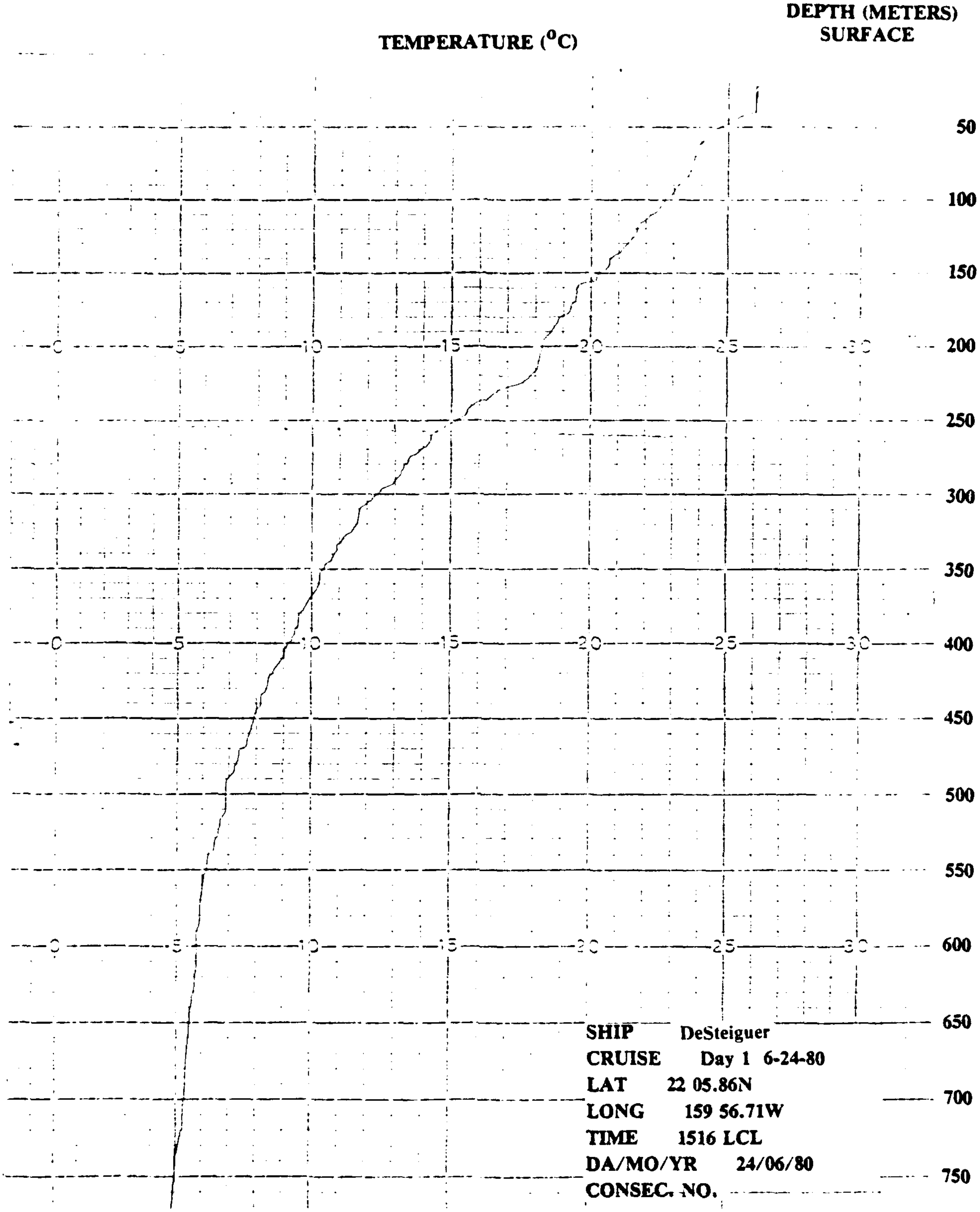


Figure 3-16. Temperature Profile 24 June 1980

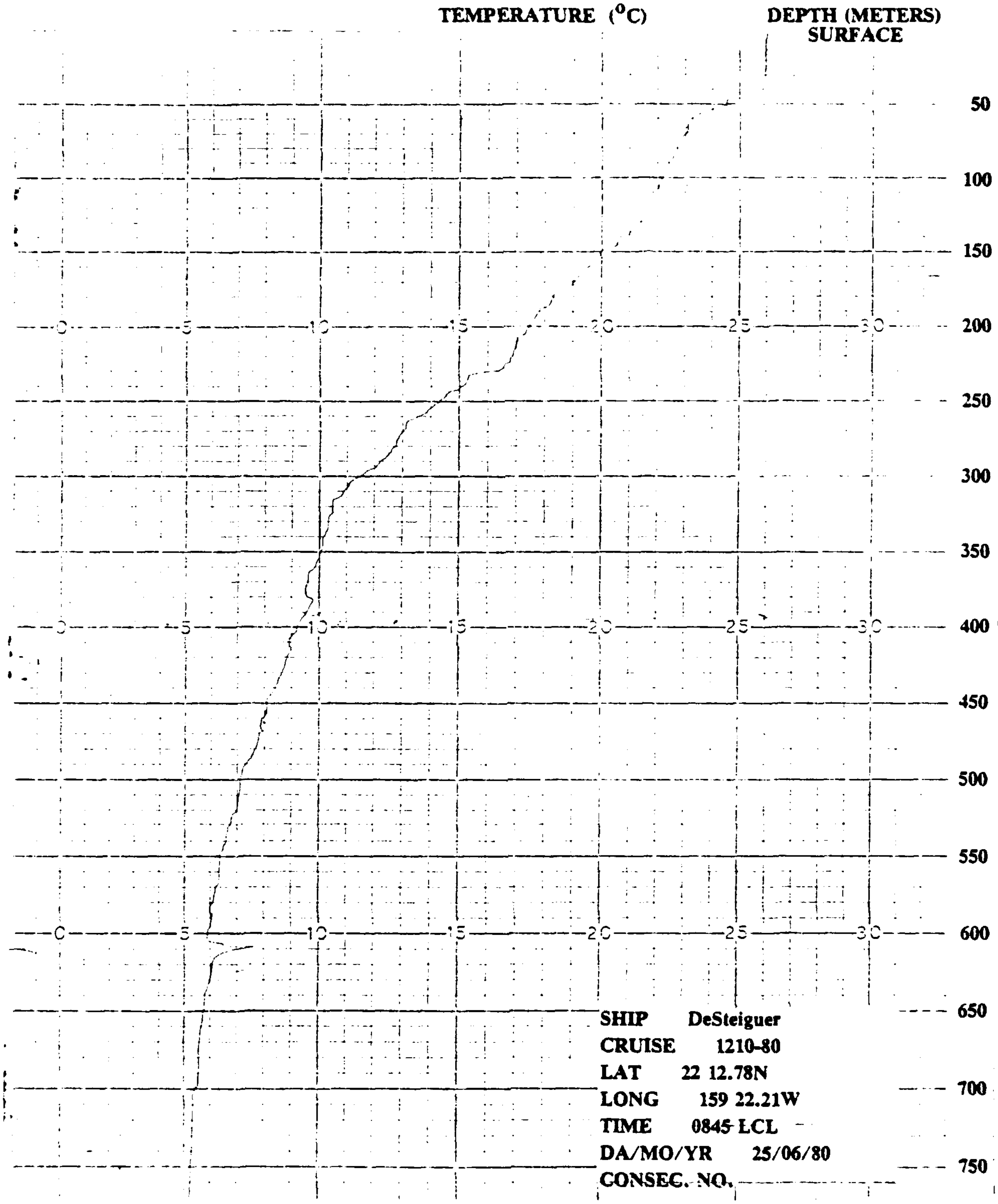


Figure 3-17. Temperature Profile 25 June 1980

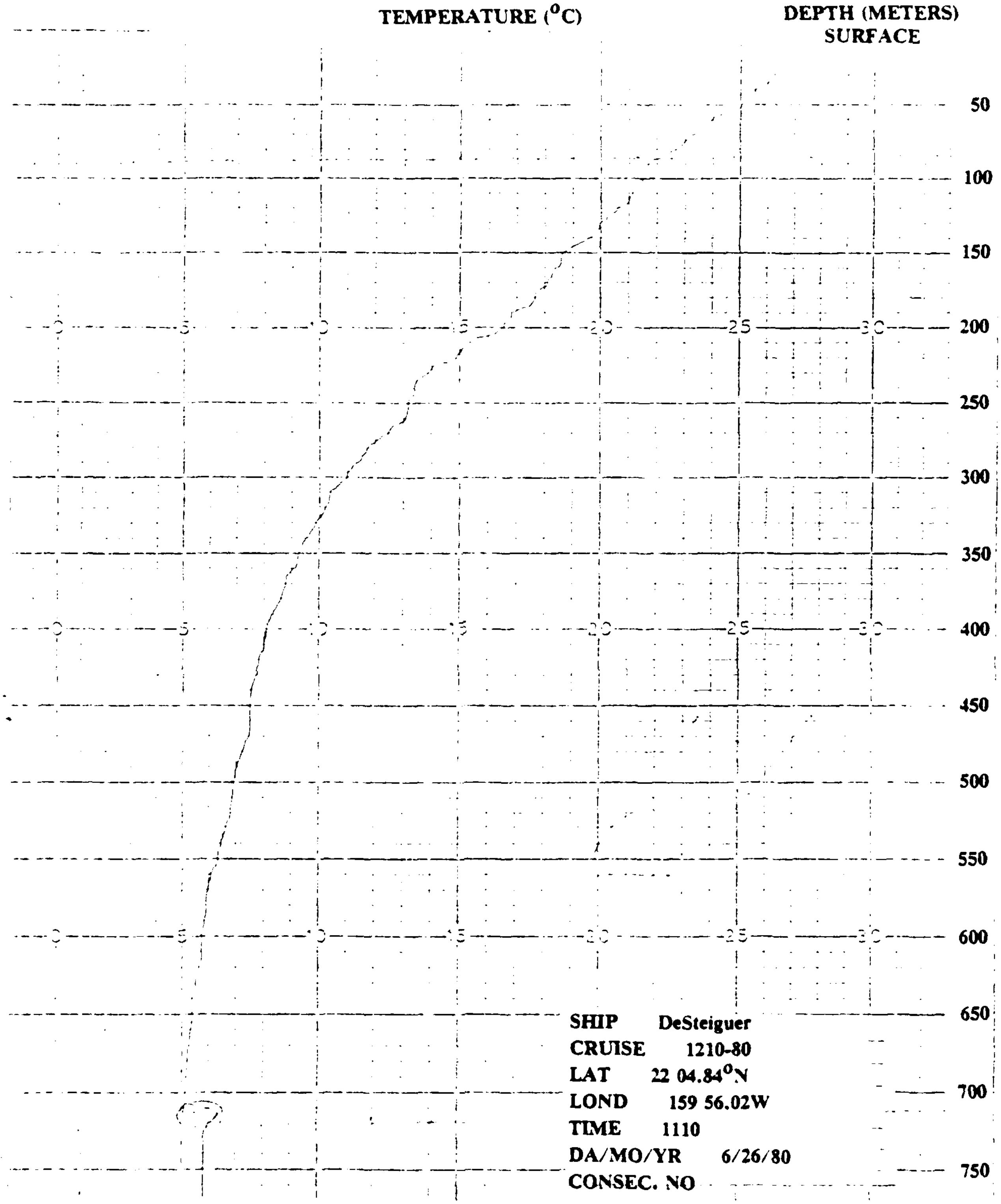


Figure 3-18. Temperature Profile 26 June 1980

Another feature of the delta depth trace is that there appears to be a long period ($\sim$5 min), low amplitude ($\sim$0.75m) oscillation of the depressor. It is unknown if this is a real motion of the depressor or if it is due to drift in the electronics. However, since this oscillation, although it is difficult to recognize, appears in the range data, the source is probably body motion.

3.3.2.2 Segment BC, 6/25

The range data and delta depth data for this segment are overlayed in Figure 3-19.

It is readily apparent that the agreement between the curves is excellent within the period of 180 to 560 seconds. With one exception at about 350 seconds, they agree to within approximately 0.6m. As with segment MN, the poor agreement at the beginning and end of this segment is attributable to hydrophone array switching. The short period oscillations apparent in the delta depth trace are probably due to ship's motion coupling since the flap angle record indicates that the ordered depth was easily maintained by the depressor. The overall depth variation indicated on the delta depth trace is less than 0.5m.

3.3.2.3 Segment NO(3), 6/25

Figure 3-20 shows the overlay of the delta depth and range data for this segment.

The range data throughout this segment is very poor. This is a further demonstration of the effects of array switching at acoustic ranges. Due to the location and course of the ship during this segment, the depressor passed through four different arrays and was never located near the center of any array area, where the best tracking occurs.

Several things can be noted from the delta depth trace. First, the body was well-behaved during this segment, with maximum recorded variations in depth of 0.66m. This segment was run with a 500m cable scope which appears to have eliminated the 6-10 second period oscillations encountered in the previous records where a 100m scope was used. However, there appear to be oscillations with a period on the order of 1.5 to 2 minutes. The explanation for this and the 5 minute period oscillation noted in segment MN is unknown. However, the amplitudes are small enough that the performance of the body is not seriously degraded.

3.3.2.4 Segment DE, 6/26

The most readily seen feature of the range data, shown overlayed with delta depth in Figure 3-21, is the overall roughness and asymmetry of the "sine" waves. The peak-to-peak amplitudes of the two series disagree between 0.6 and 5.5m, with the best agreement occurring at the beginning and end. The larger amplitudes exhibited by the middle portion of the range data are probably due to array switching. Array switching probably accounts for the overall upward slope of the zero crossings of the range data. Five separate arrays were used during this segment with switching occurring at approximately 120, 320, 600 and

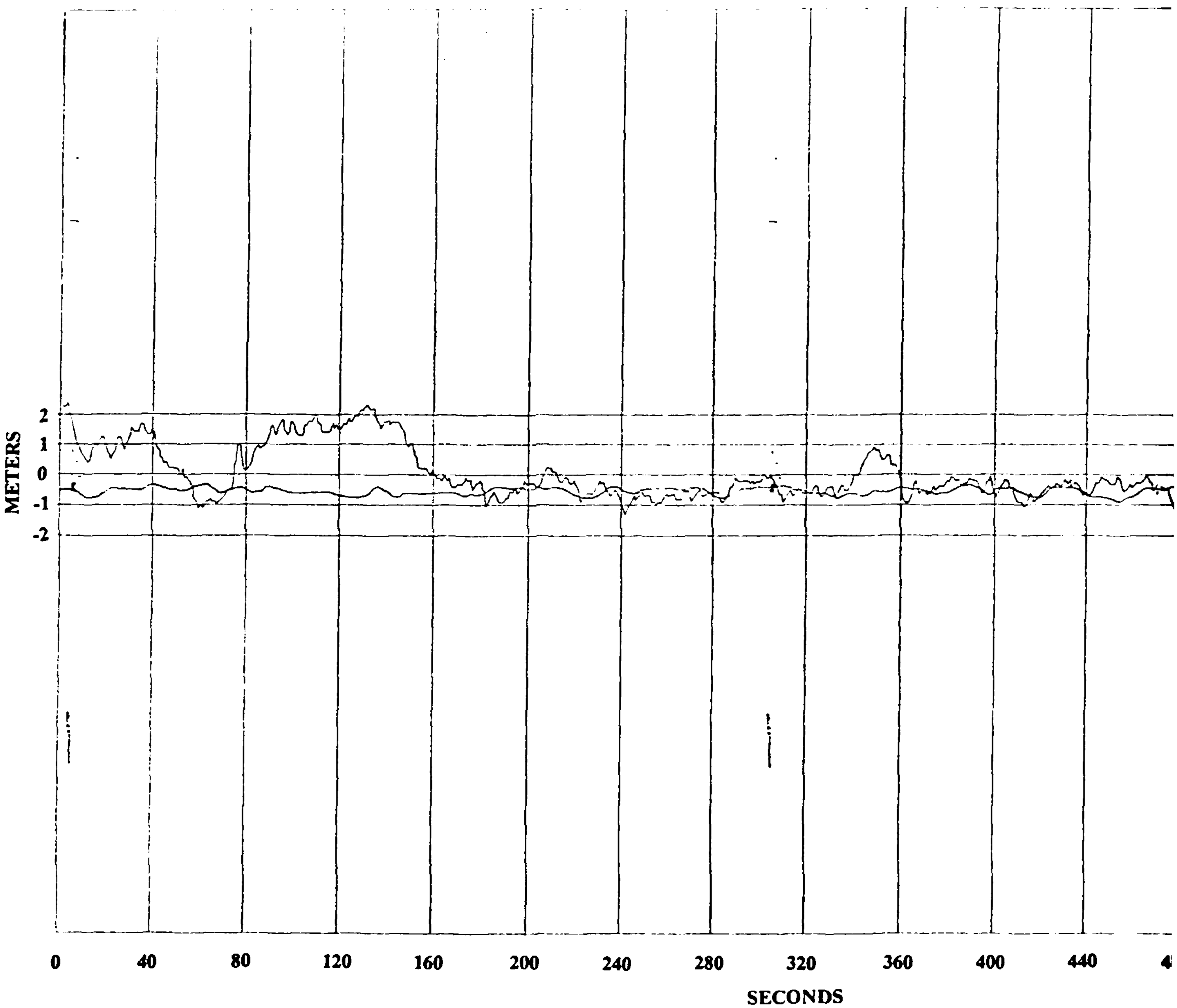
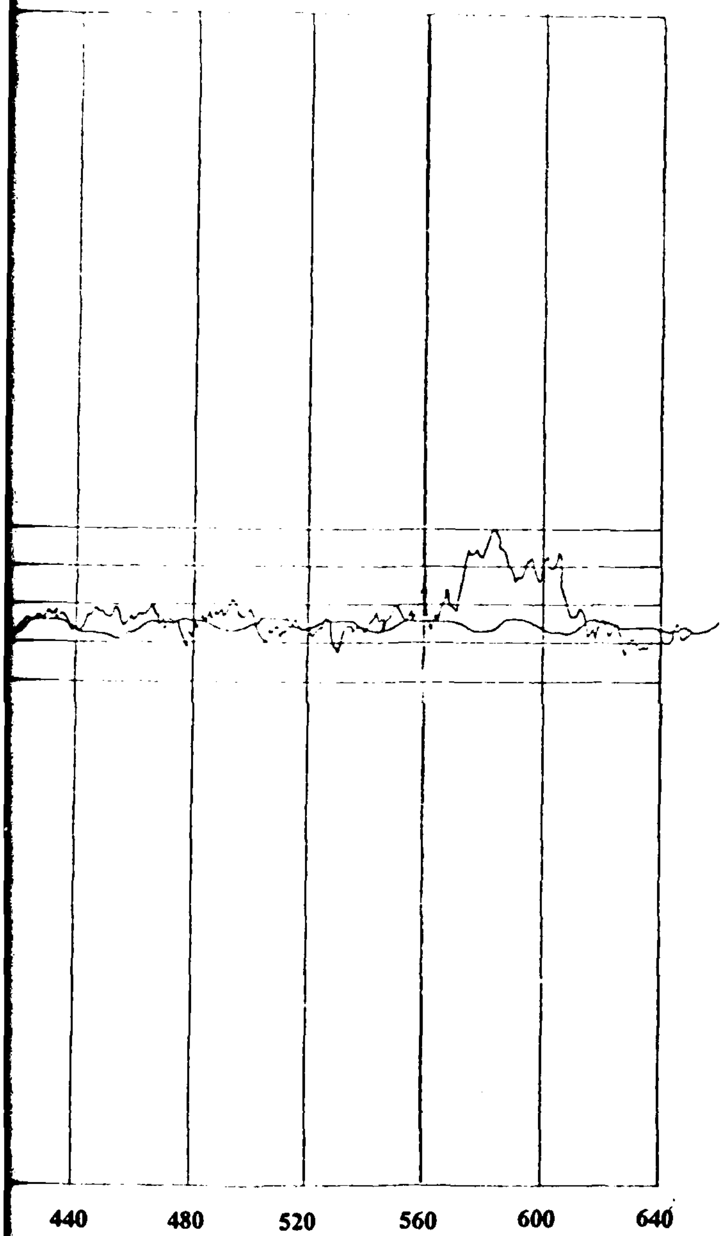


Figure 3-19. Segment BC Range and Δ Depth Data



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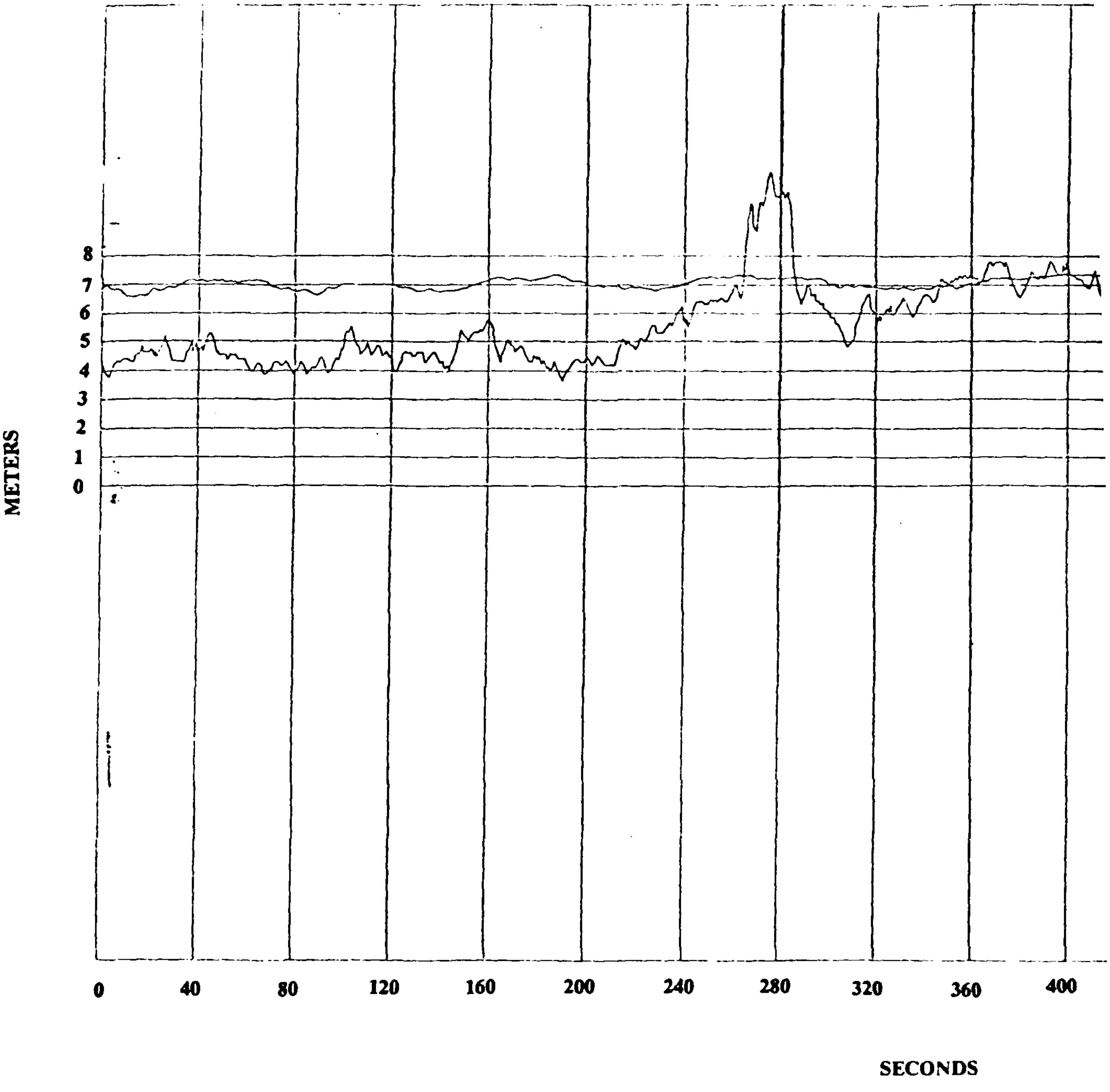
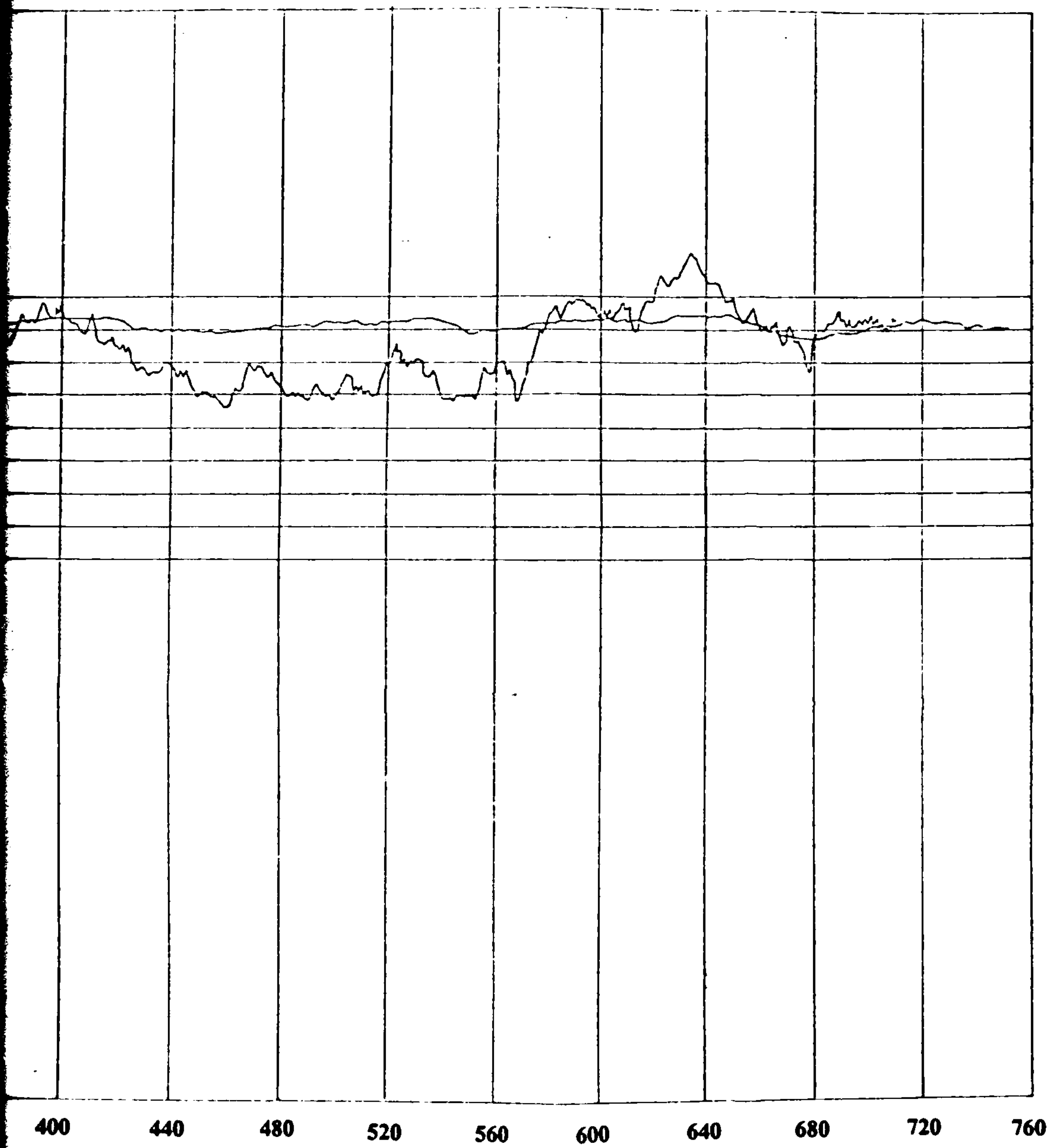


Figure 3-20. Segment NO(3) Range and



ge and ΔDepth Data

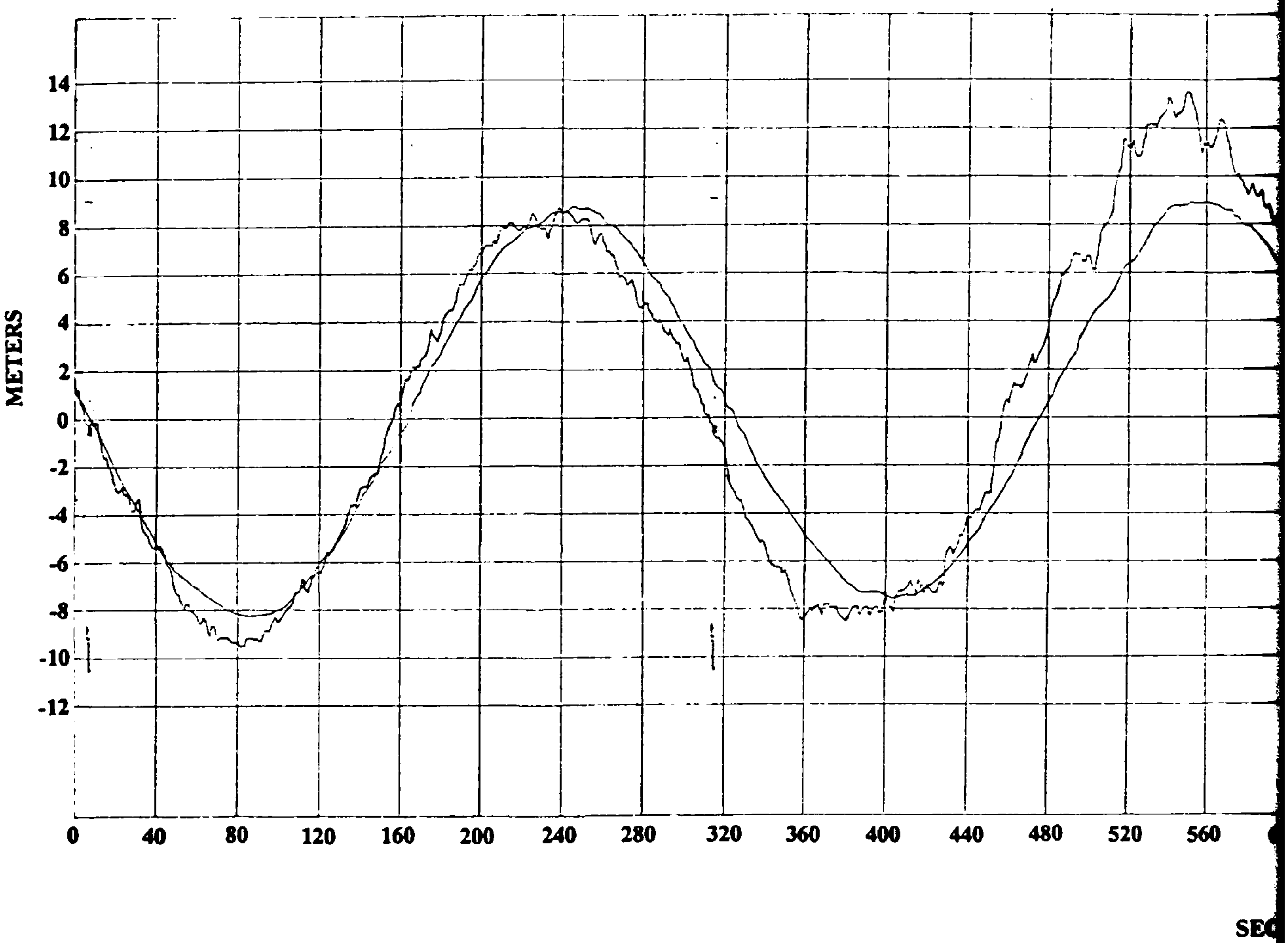
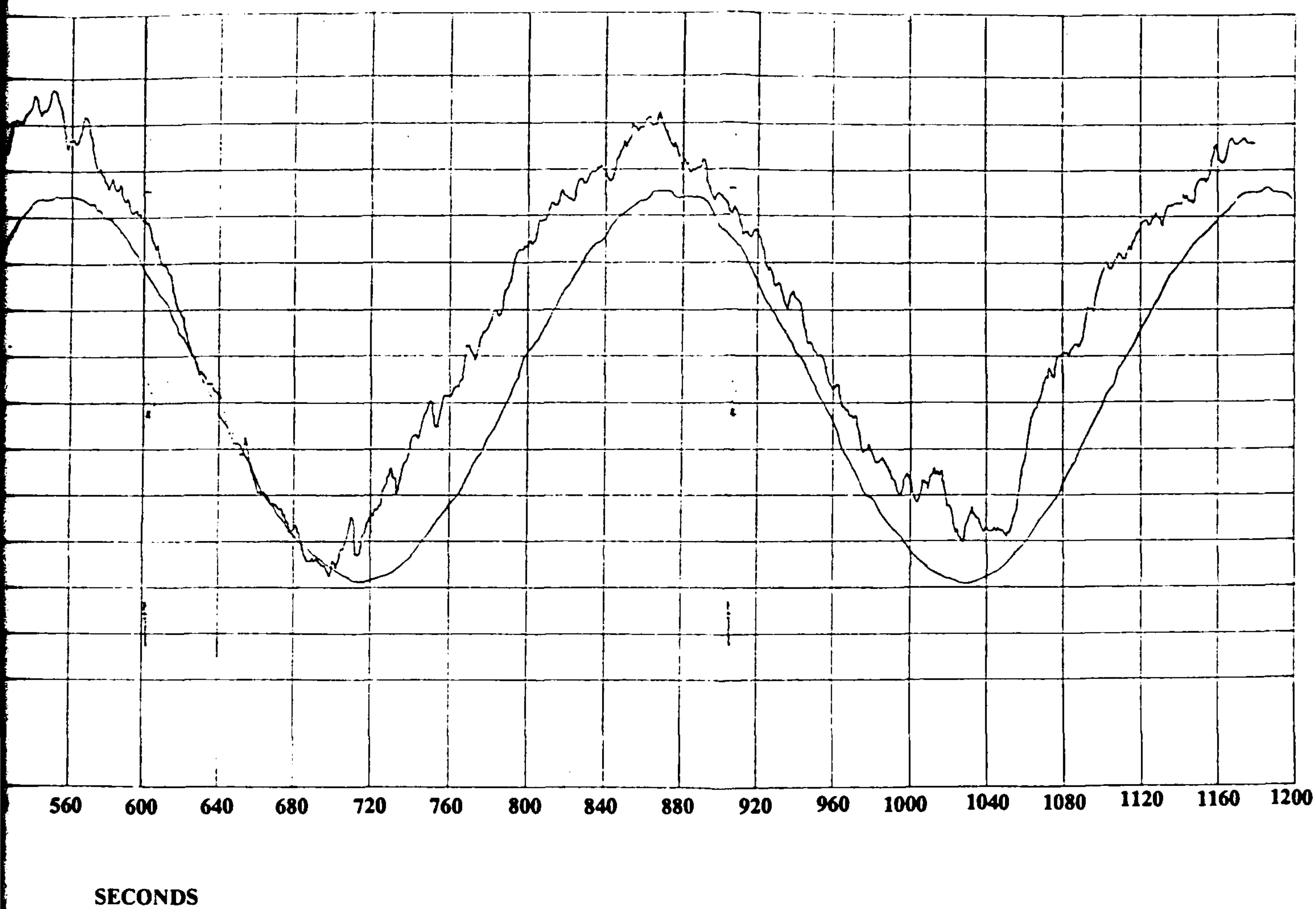


Figure 3-21. Segment



Segment DE Range and Δ Depth Data

630 seconds. The cause of the generally rough nature of the range data is unknown, but may be due to the fact that while the depressor is cycling, the axis of the pinger beam pattern changes direction, thus calling different hydrophones into use.

One final item to be noted is that although the frequency was set to 0.003 Hz, the actual frequency is 0.00313 Hz.

3.3.2.5 Segment JK, 6/26

Although the general shape of the range data, shown in Figure 3-22, is smoother during this run than in Segment DE, there are again large differences in the peak-to-peak amplitudes. The range data shows amplitudes between 0.3 and 3.3m larger than the delta depth data. This difference, as well as the downward then upward slope of the range data envelope, may be accounted for by array switching. The body was towed over one array during the first four minutes, a second array for the next 6.5 minutes and a third array for the last 1.5 minutes. As noted earlier, with the body in a cycling mode hydrophone switching could occur at other times depending on the location and attitude of the body.

Another possible explanation for the sloping of the range data envelope is that there may be a drift in the electronics that is not detected by the body circuitry.

It can be noted in Figure 3-22 that the body rises faster than it descends. The ordered period for this segment was 100 seconds however, the body rises in 46 seconds and descends in 50 seconds.

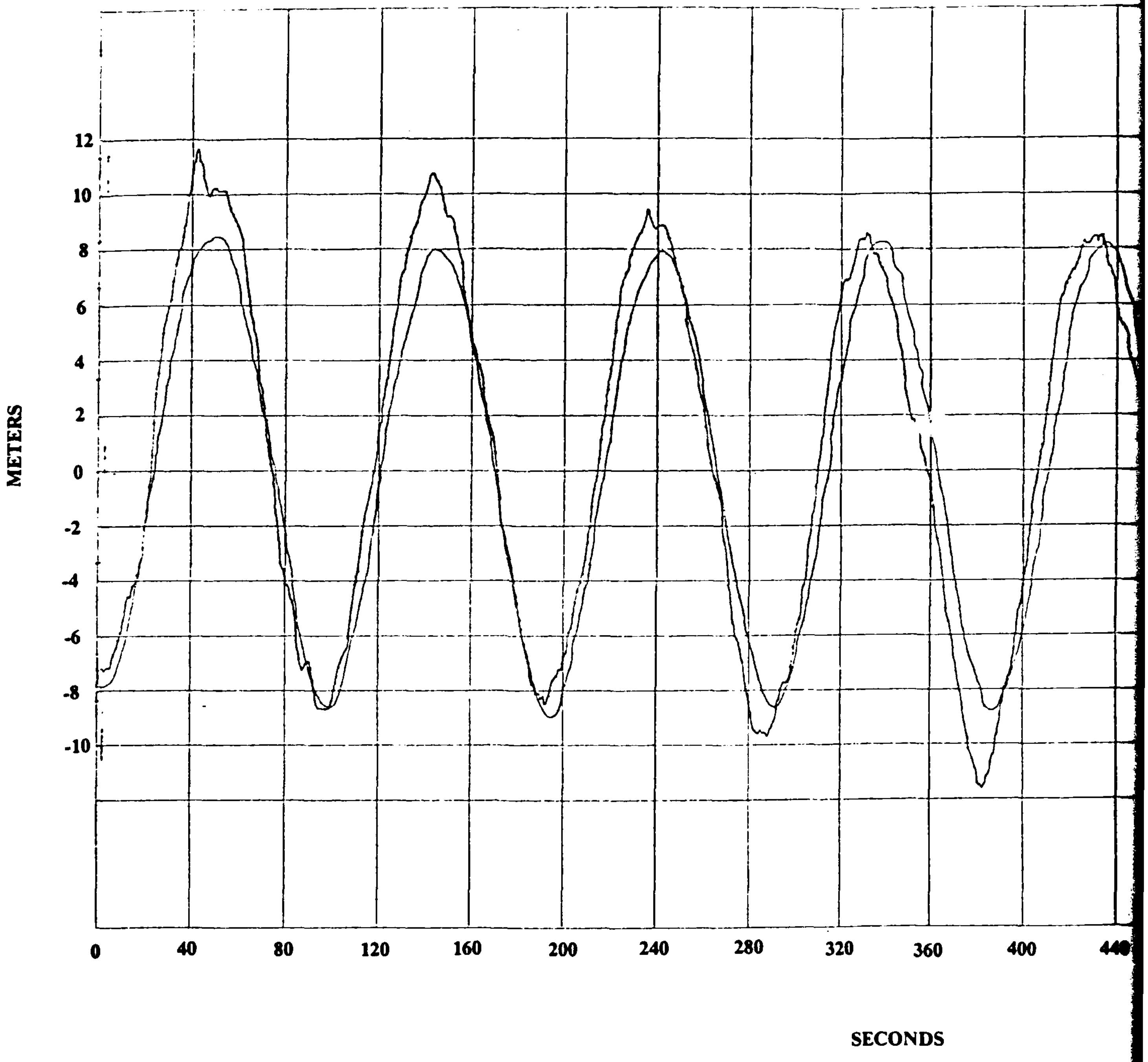
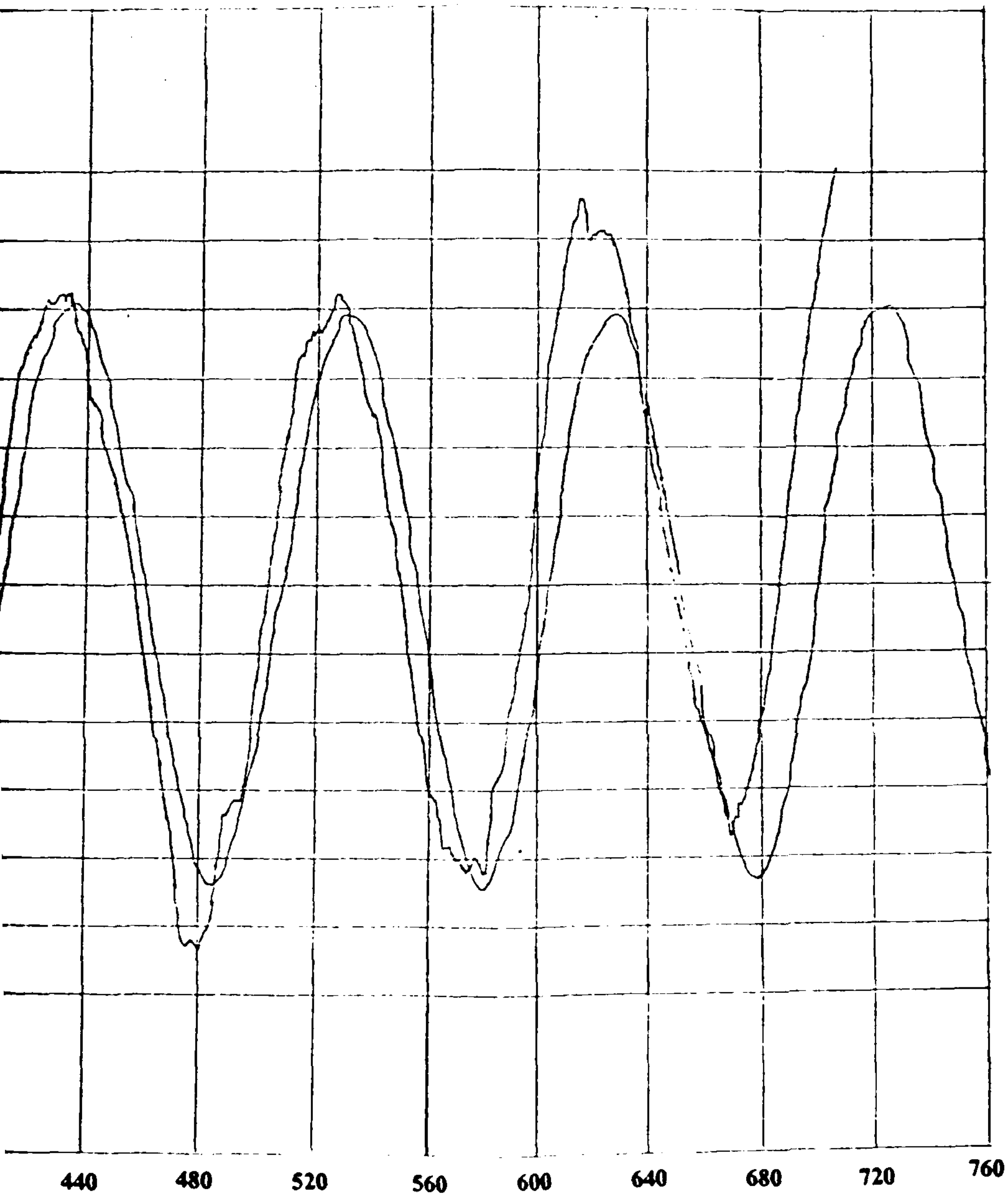


Figure 3-22. Segment JK Range and Δ Depth



Depth Data

Section 4

CONCLUSIONS AND RECOMMENDATIONS

This section summarizes the conclusions that can be drawn from the test data as well as some practical things that were learned during the test, and makes recommendations.

4.1 DATA QUALITY

The general conclusion that can be drawn from the comparison of the range data to the delta depth data is that although the point-to-point accuracy of ± 3 feet requested from the range was fulfilled, the delta depth data has much better absolute accuracy. Neither data set by itself is sufficient to prove the absolute performance of the body, but the range data serves to corroborate the delta depth data.

This report has only dealt with the data obtained for the depressor. However, another investigator, Mr. Michael Karweit of Johns Hopkins University, has performed some computer processing of both the body and ship data to determine the extent to which coupling occurs. His investigation, a portion of which is included as Appendix A, showed that the ship data is of such poor quality that the answer is not attainable.

4.2 BODY PERFORMANCE

Given the conclusion that the delta depth data is the most accurate, how well the depressor performs can be assessed.

The depth keeping ability of the depressor when in the constant depth mode is excellent when the body is being operated properly. What is meant here is that the combination of cable scope and tow speed are optimized so that the ordered depth is such that the depressor is operating in a region of high tension coefficient, as discussed in Reference 1. This was the case during Segments BC and NO(3).

Each of these segments indicates that the depressor maintained constant depth throughout the run to ± 0.33m. During segment NO(3) a 500m cable scope was used, thus attenuating ship coupling to a greater degree than in BC, and this enabled the body to maintain constant depth to ± 0.09m for periods on the order of one minute.

Even in segment MN, when scope and speed conditions were somewhat marginally optimized for the particular depth ordered, the total depth variation for the run was only ± 0.5m. However, the short period stability was not as good as during BC or NO(3).

The delta depth traces from segments DE and JK show that the body performance is also very good in the cycling mode. During segment DE, the body maintained the same peak-to-peak amplitude to within 0.6m, and except for some minor irregularities traced a smooth sine. The trace from segment JK is not quite as smooth as DE, and as noted before has a steeper rise than descent. However, the peak-to-peak amplitude variation was again only 0.6m.

Although the performance of the depressor in the X-Y plane has not been examined thoroughly, a cursory examination of the range-generated X-Y plots indicates that the body track parallels that of the ship very closely, probably to within several meters.

To summarize, it is felt that the depressor performs very well. When in a constant depth mode, the body maintains its depth to within ± 0.33m for periods of at least 12 minutes. When decoupled from the ship by a long cable scope, it is capable of maintaining depth to ± 0.09m for periods of about one minute. Therefore, at any given second in time, the body is known to be within a $10m^3$ volume of water for a 10 knot tow speed.

4.3 OPTIMIZING PERFORMANCE

As mentioned in Section 4.2, achieving good body performance hinges on selecting the proper combination of scope and speed to achieve the desired depth. Although the predicted performance curves shown as Figure 2-2 are a good starting point, experiences during the test showed that they are not totally valid under at-sea conditions.

As previously mentioned, some of the depths selected during the writing of the test plan were not achievable. Additionally, some of the segments that were run during the test were marginal. As a rule of thumb, if the flap angle remains within ± 17°, the body will be performing well.

Most of the four knot segments run had portions during which the depressor did not perform well, probably due to the inability of the ship to maintain speed in the seas. An examination has been made of the delta depth records to determine which scope and speed combinations tested were capable of producing the desired depth (constant and cyclic) to within ± 0.5m for greater than 75% of the run. These are listed in Table 4-1.

In general, at a particular depth if the scope/speed/ depth combination falls toward the high tension coefficient portion of the predicted performance curves, the body will perform well.

A general statement of an optimum operating envelope; as deduced from Table 4-1, is that for a 50m desired depth,use 100m of scope at any speed. To achieve 150m depth, use 500m of scope at 7-10 knots.

Table 4-1. High Performance Test Segments

Scope (m)	Speed (kts)	Ordered Depth (m)	Input Frequency (Hz)	Input Amplitude
100	4	55	--	--
100	4	50	--	--
100	4	50	.007	max
100	4	50	.01	½ max
100	7	65	--	--
100	7	40	--	--
100	7	40	.003	max
100	7	40	.003	½ max
100	7	40	.007	max
100	7	40	.007	½ max
100	7	40	.01	max
100	7	40	.01	½ max
100	6	45	--	--
100	8	25	--	--
100	10	20	--	--
100	10	60	--	--
100	10	40	--	--
500	5	160	--	--
500	5	130	--	--
500	7	150	--	--
500	10	150	--	--
500	10	100	--	--
500	7	125	.003	max
500	7	125	.007	max
500	7	125	.007	½ max
500	7	125	.01	½ max
500	7	125	.01	max
500	10	125	.003	max
500	10	125	.007	max
500	10	125	.01	max
500	10	125	.01	½ max
500	10	125	.007	½ max
500	10	125	.003	½ max
100	10	50	.003	max
100	10	50	.007	max
100	10	50	.01	max
100	10	50	.01	½ max
100	10	50	.007	½ max
100	10	50	.003	½ max

4.4 MEASUREMENT SCALES

The test results have proven that the depressor is very well behaved in a hydrodynamic sense. However, the question of what are its limits in terms of CTD measurements and the spatial scales over which they can be made needs to be more fully addressed.

The bulk of the analysis has dealt with the depressor's depth keeping ability, and the vertical scale of measurement capability has been established at ± 0.33m for periods of at least 12 minutes which equates to an along-track distance (at 10 knots) of 3706m. However, for periods of about one minute the body is capable of depth-keeping to ± 0.09m for one of the segments examined. This equates to an along-track distance of 309m (at 10 knots).

The depressor's lateral stability is more difficult to define. A visual examination of the range data indicates that the body track does not deviate from the predicted track any greater than the resolution of the range (± 3 feet) for the duration of the segment. The lateral motion of the body is most probably smaller than this, but without installing accelerometers the motions cannot be resolved to any greater degree.

To summarize, it can safely be said that the depressor is where it is ordered to be to ± 0.33m in depth and ± 1m perpendicularly to the direction of tow for periods of 12 minutes, and potentially to ± 0.09m in depth and ± 1m perpendicularly to the direction of tow for periods of 1 minute when using a long cable scope.

4.5 ACOUSTIC TRACKING RANGE

This subsection addresses the general issue of using an acoustic tracking range for high resolution measurements.

The analysis of the data reported on here has pointed out some things that should be kept in mind if future use of an acoustic range for a similar purpose is anticipated.

The decision to use the BARSTUR range was made after receiving assurance from PMRF personnel that a point-to-point accuracy of ± 3 feet was achievable. It is believed that this accuracy was attained for the depressor, but not for the DeSteiguer. This may be due in part to the necessity of placing the ship's pinger where at times it was exposed to entrapped air, depending on the motion of the ship.

Naturally, when array switching occurred the accuracy of the data was severely degraded. This also occurred when the path of tow was close to the edge of an array.

Generally though, satisfactory results can be achieved by planning for and maintaining the track such that it nearly bisects the triangle formed by the array.

4.6 MISCELLANEOUS OBSERVATIONS

Some practical experience with the towed CTD system that may be of use to future users is discussed below.

4.6.1 Deployment and Retrieval

Deploying and retrieving the depressor is somewhat cumbersome, particularly when using the remote sensors. However, if the ship is headed into the seas and a 3-4 knot speed is maintained, the difficulty is minimized. Consideration should be given to towing from the port or starboard side, rather than the stern, as attachment of remote devoces would be easier in this mode.

4.6.2 Turns

During ship turns, speed should not exceed 7-10 knots to prevent excessive tension buildup. Also, regardless of direction of the turn, the depressor comes inside the turn and sinks.

4.6.3 Kiting

During a majority of the runs, the depressor kited, at times severely, to the port side. However, this was mostly due to the fixed remote sensor attachment point. It is believed that this will be alleviated with the use of a free-swiveling clamp.

4.7 RECOMMENDATIONS

The good performance of the depressor minimizes the number of recommendations that can be made, but there are a few.

The sloping of the envelope of the cycling segment traces is probably due to array switching, but bench testing for zero drift should be done to verify that drifting is not occurring.

In order to minimize the possibility of kiting, the remote sensor attachment clamp should be redesigned to permit swiveling.

The onboard display and recording equipment should be upgraded. The ship chart recordings are useful for real-time visualization of the behavior of the body, but recording the data on tape would be valuable.

It is felt that the depressor is ready for installation of the CTD system and complete system checkout.

REFERENCES

1. Knutson, R. and R. Singleton, Operation and Hydrodynamic Evaluations of a Controlled-Depth Towed Depressor Designed to House a Conductivity, Temperature, Depth (CTD) Instrument System, DTNSRDC, May 1980.

2. Hesselbacher, T.H., Test Plan for Measuring the Motions of a Modified Minesweep Depressor, MAR, Incorporated Test Plan No. 117, May 1980.

APPENDIX A

APPENDIX A

The following describes the analysis procedure used by Mr. Michael Karweit of Johns Hopkins University in processing the ship and depressor range data and presents a few examples of the results he obtained.

The remainder of his results as well as a complete data package resulting from the BARSTUR test are located at NORDA, Code 540.

Data Reduction Procedure

1) Unpack raw data. Round time to nearest second and produce the time series: XS(t), YS(t), ZS(t), XB(t), YB(t), ZB(t).

2) Scan these series for missing values (seconds). If there are three or fewer consecutive seconds missing, do a linear interpolation to fill the gap and flag with a "1". If more than three, flag with a "2".

3) Of the typically 700 seconds long runs, find the "best" 512 second segment on which to do analysis.

4) Generate the following time series for analysis:

   ZB(t) = depth of tow-body (ft)
   ZS(t) = depth of ship (ft)
   VPB(t)= velocity of tow-body parallel to avg. ship bearing (ft/sec)
   VNB(t) = velocity of tow-body normal to avg. ship bearing (ft/sec)
   SS(t) = speed of ship (ft/sec)

   Note: avg. ship bearing is calculated from pos'n of ship at beginning and end of 512 sec segment.

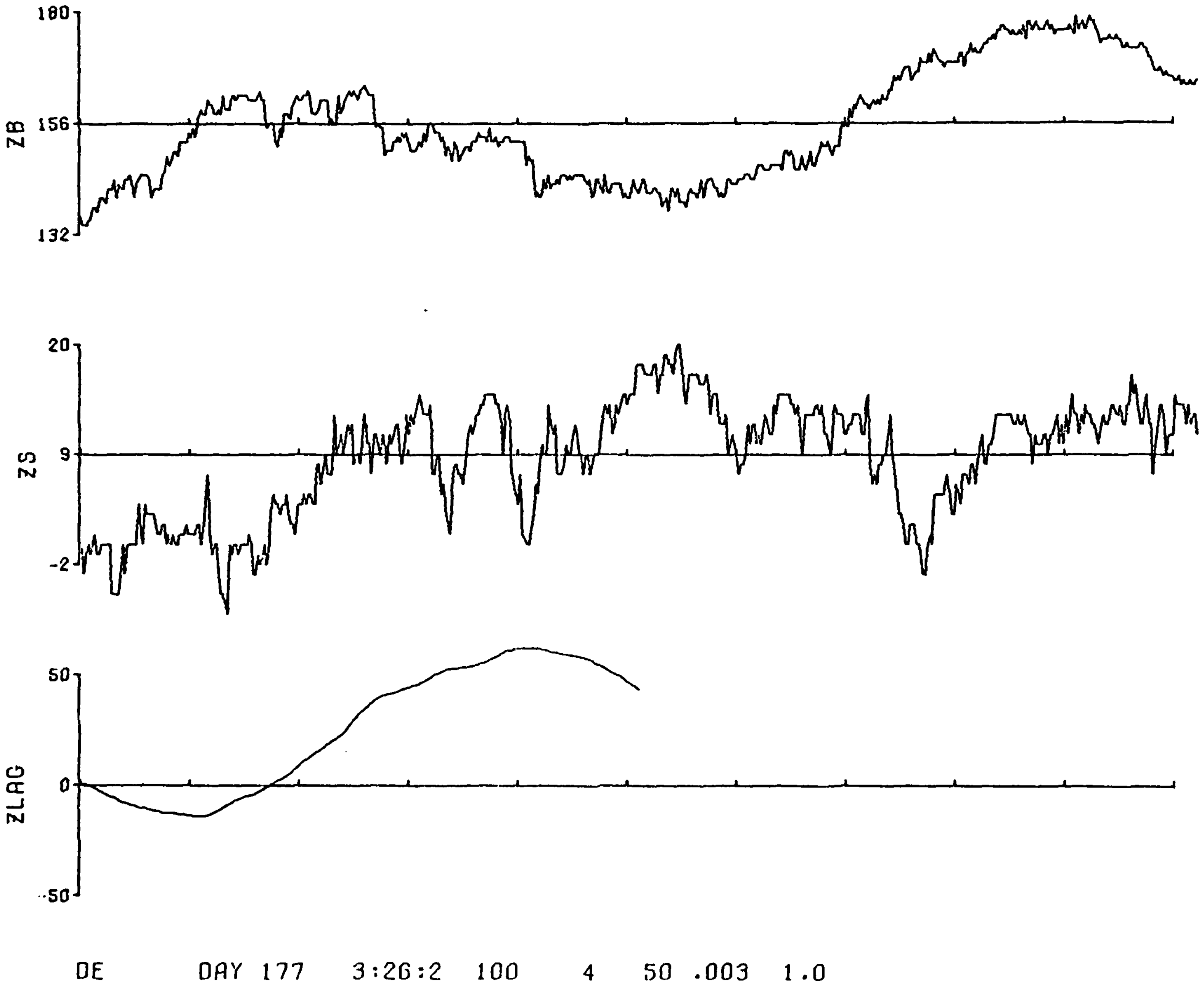
5) Calculate results:

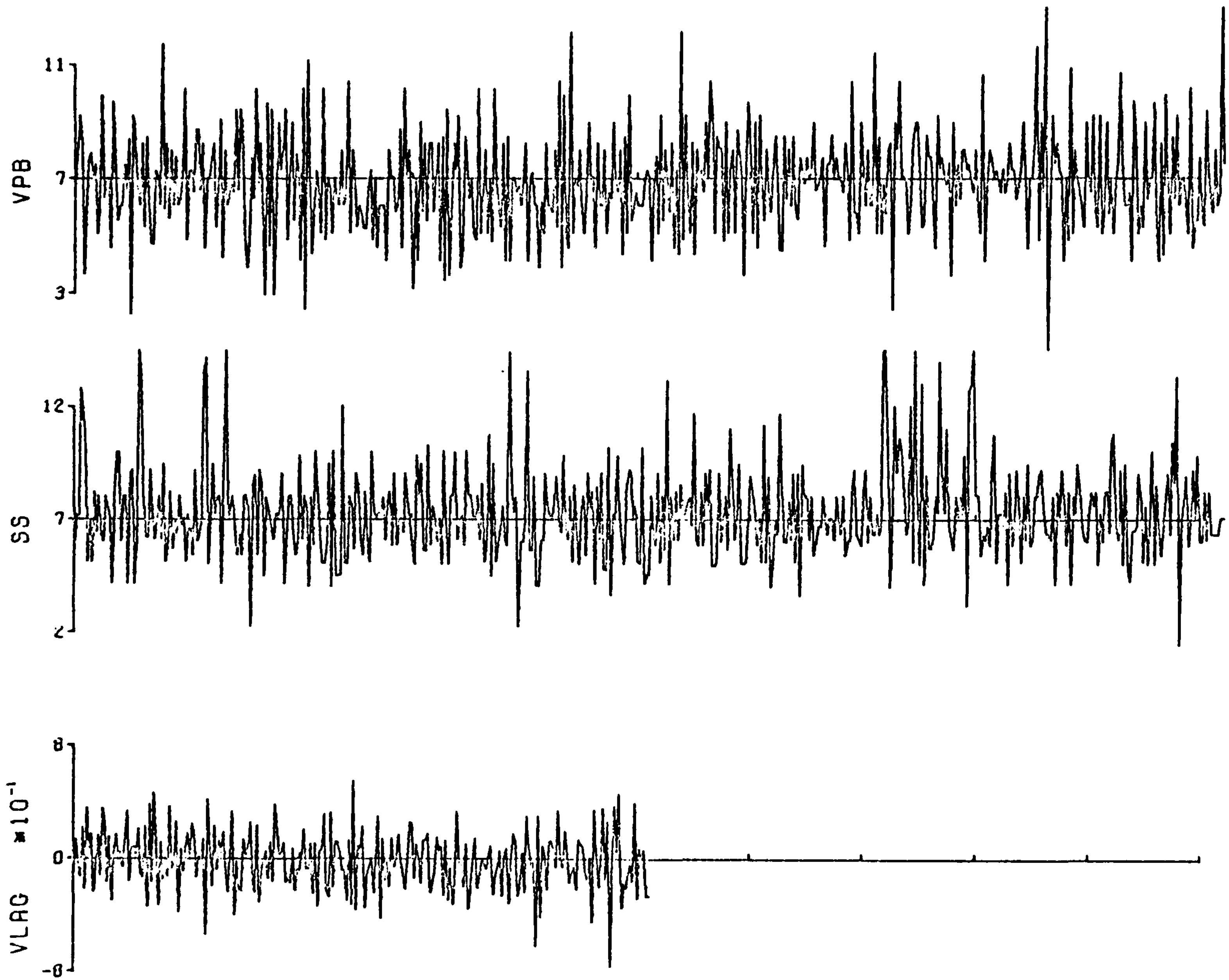
   a) Calculate avg value of each of the five time-series.

   b) Replace "2's" with avg. value and plot

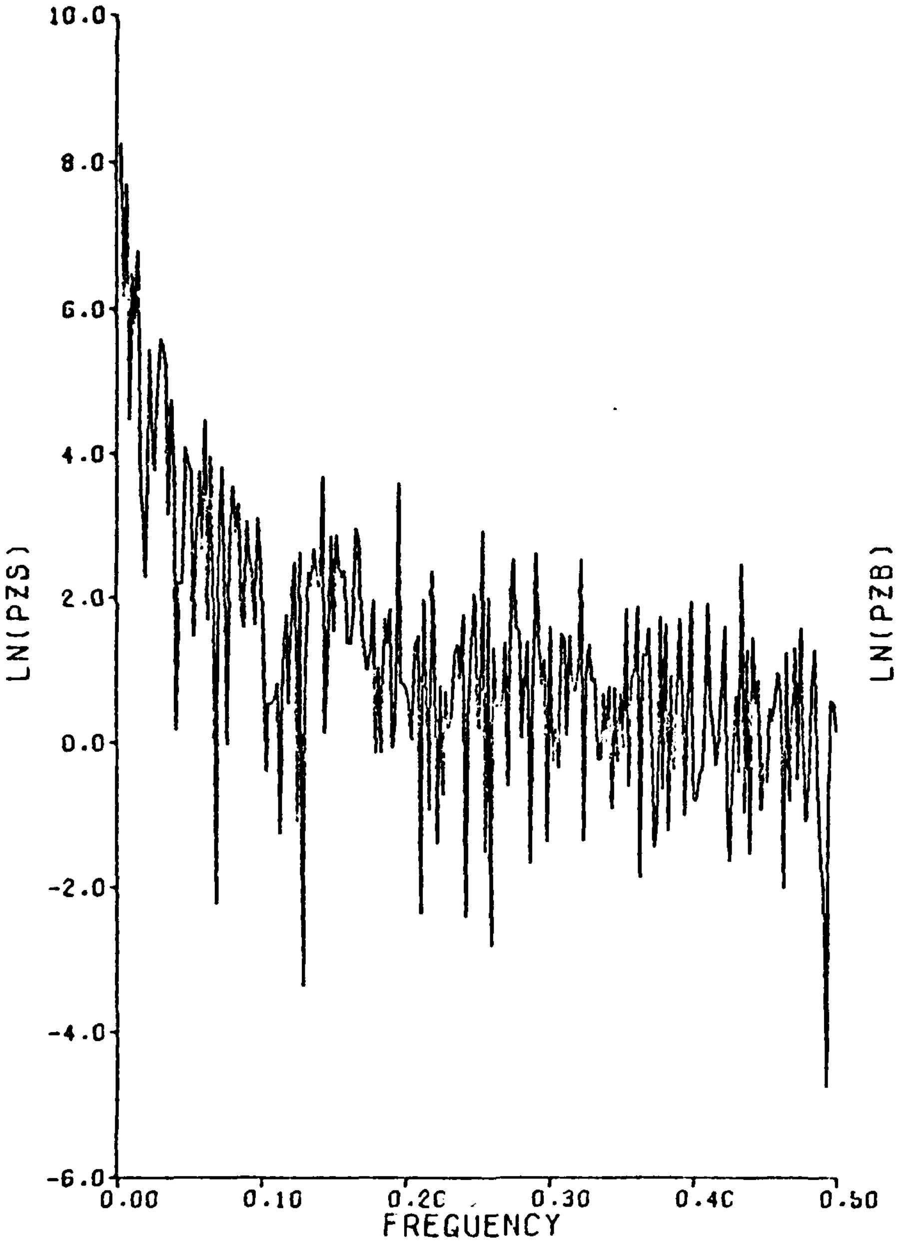
   c) If no "2's", remove trend, calculate variance, and calculate and plot power spectrum (ft^2/df)
   Power(ZB(t)) = PZB(f), etc.

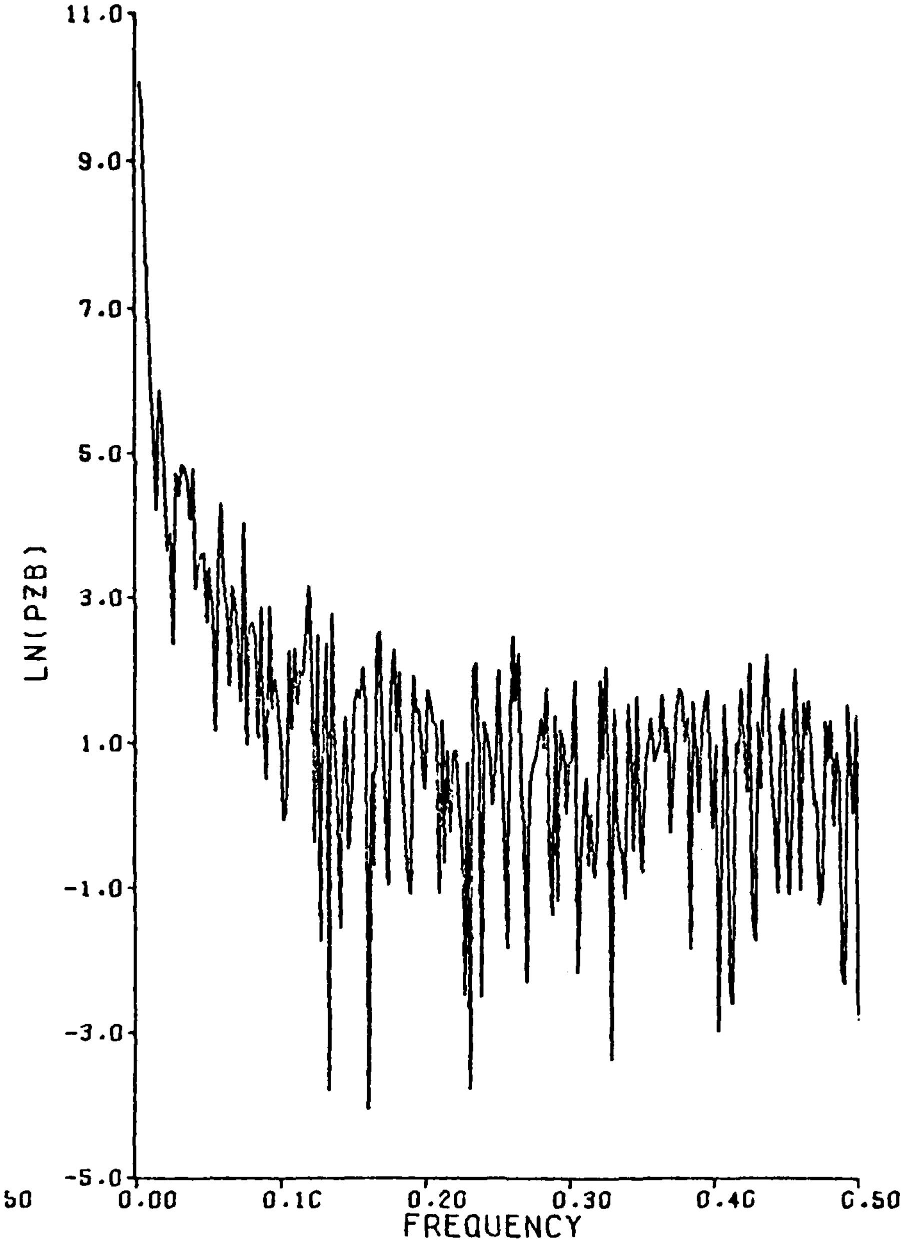
   d) If no "2's" in either tow-body or ship data, calculate and plot lagged covariances
   $ZLAG(T) = \overline{ZB(t) * ZS(t+T)}$, $\overline{VLAG(T) = VPB(t) * SS(t+T)}$


180
156
132
ZB
20
9
-2
ZS
50
0
-50
ZLAG
DE DAY 177 3:26:2 100 4 50 .003 1.0

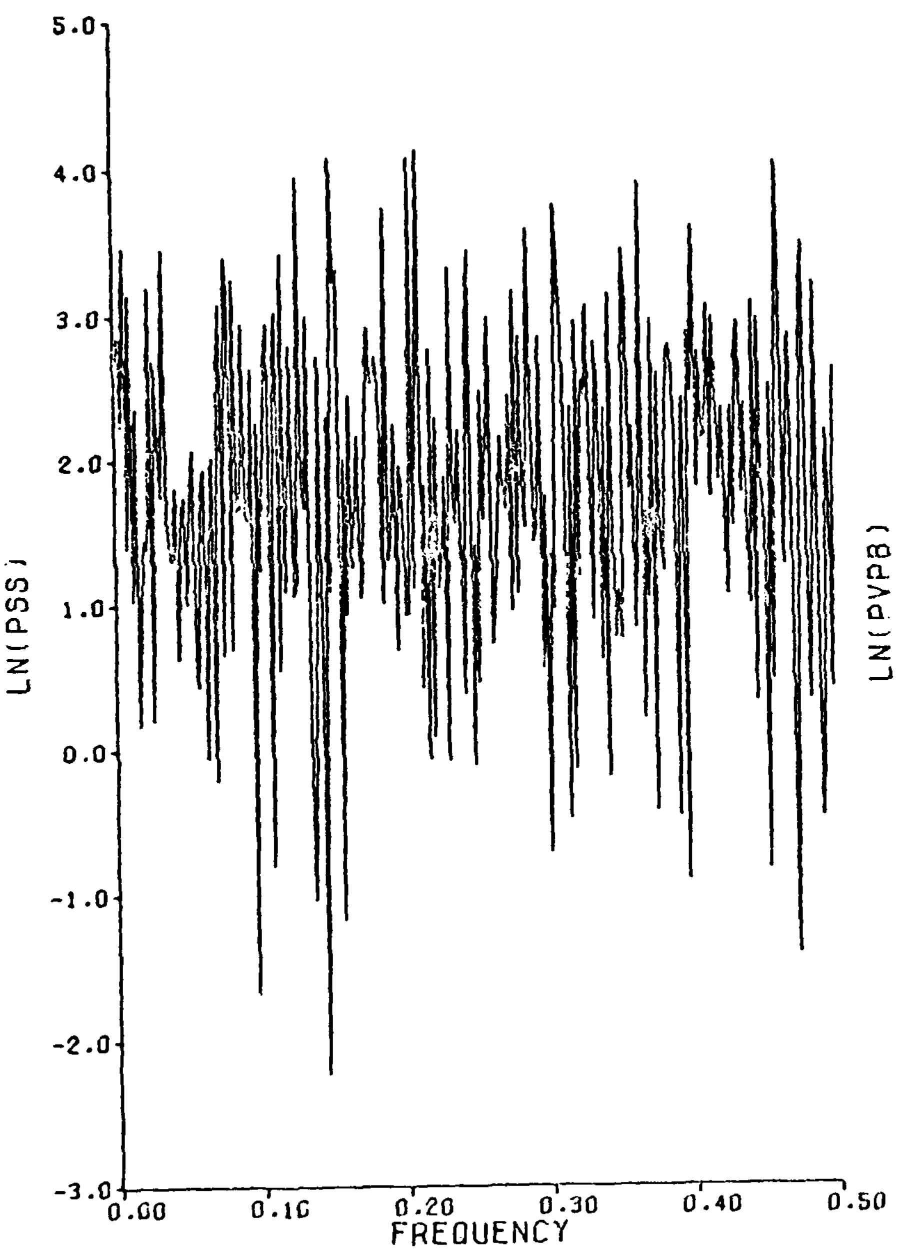


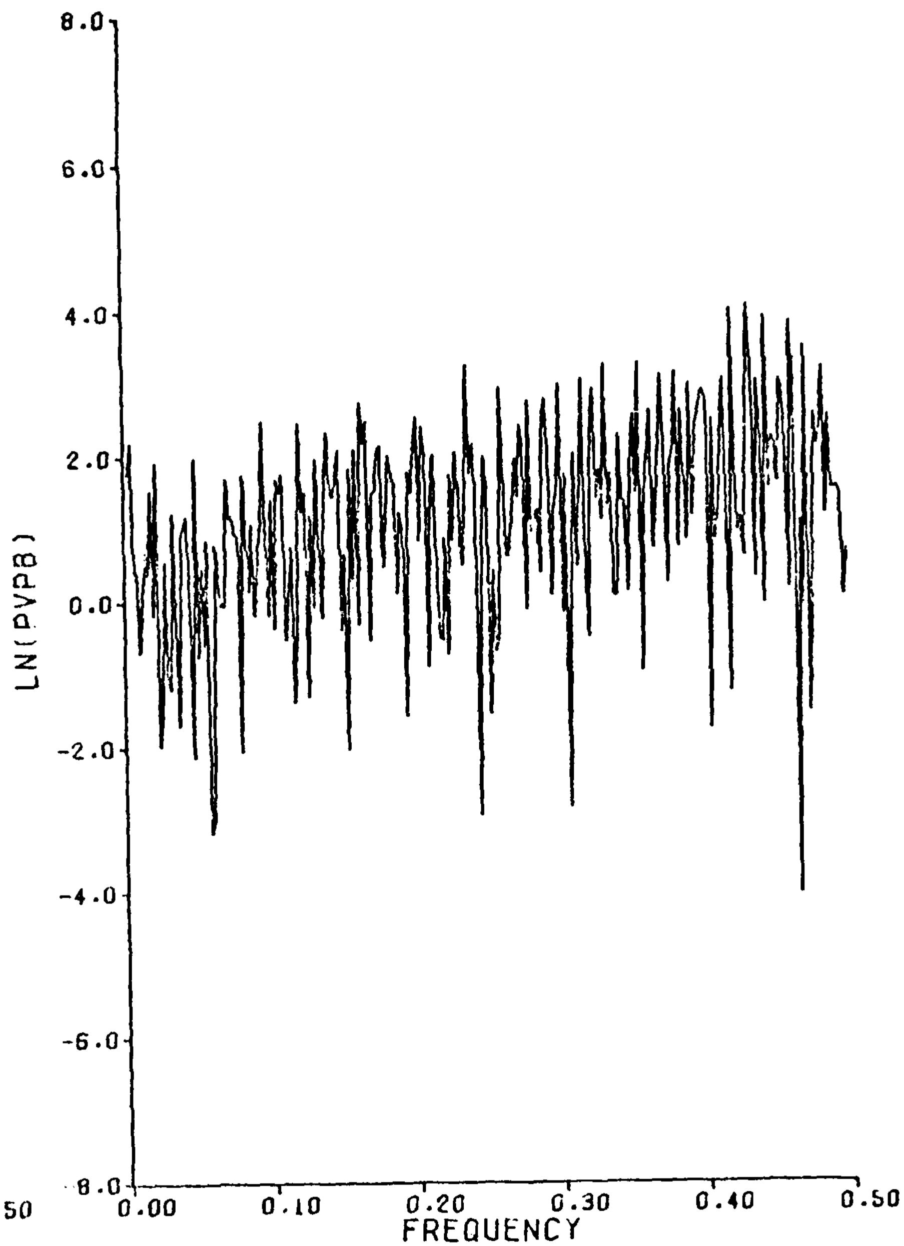
DE DAY 177 3:26:2 100 4 50 .003 1.0



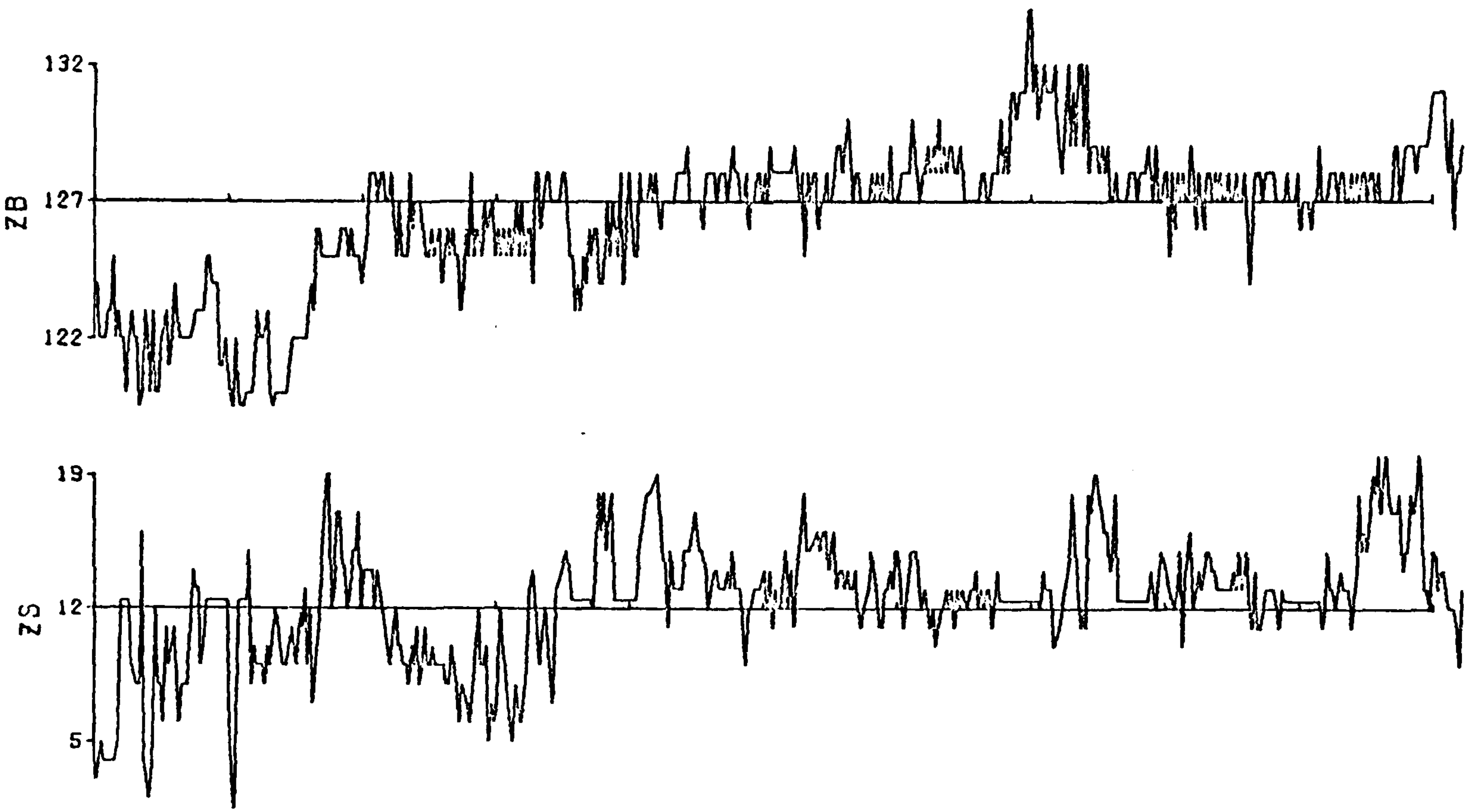


DE DAY 177 3:26:2 100 4 50 .003 1.0

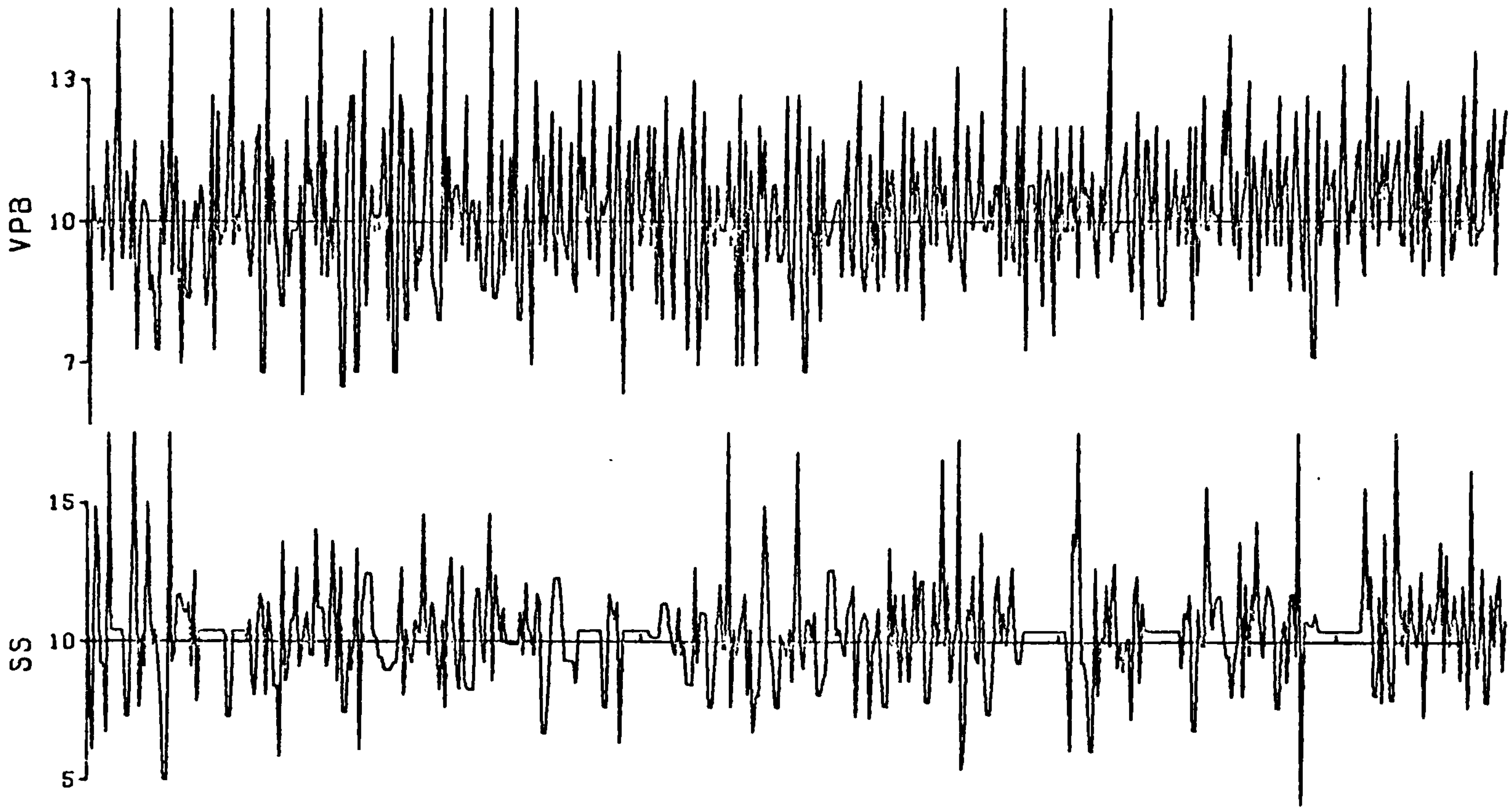




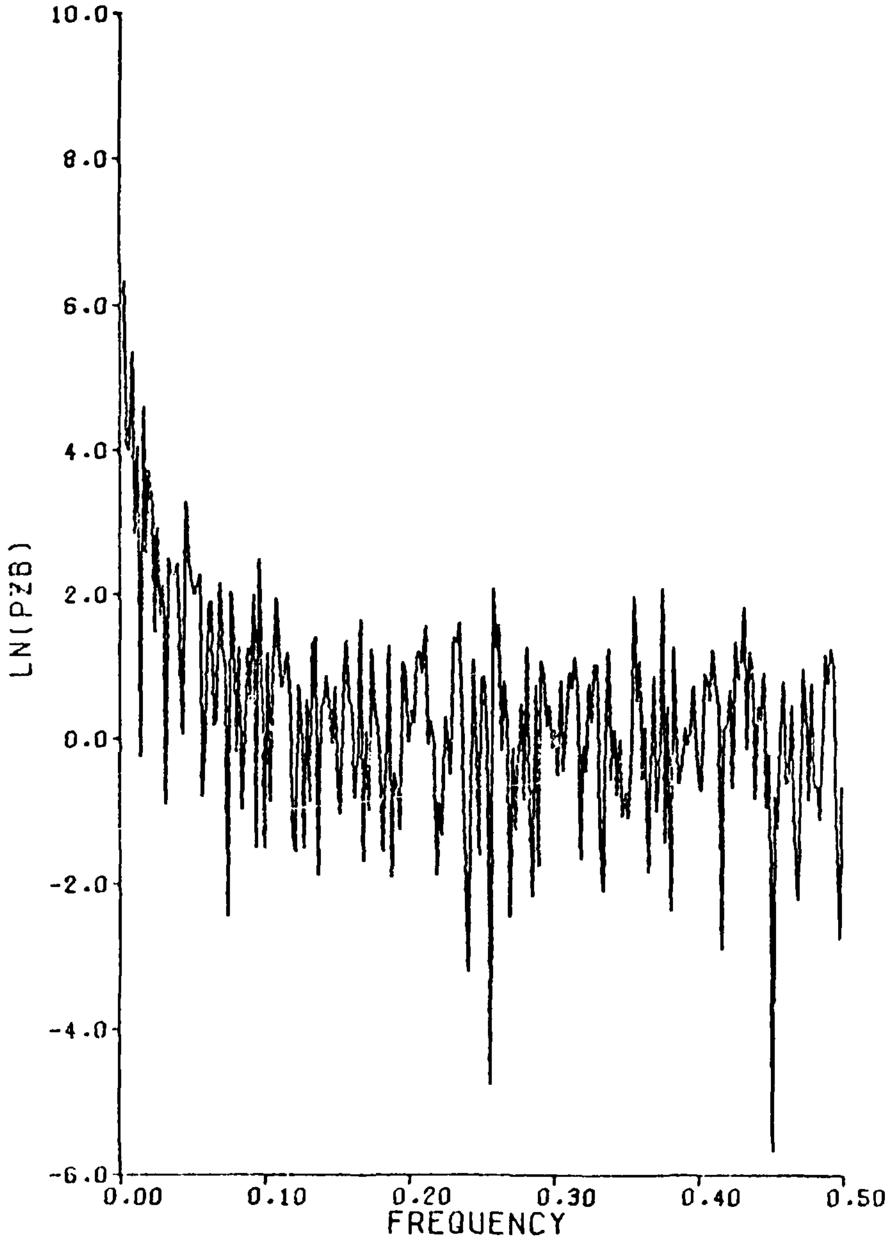
DE DAY 177 3:26:2 100 4 50 .003 1.0



MN DAY 177 6:30:2 100 7 40 .000 0.0



MN DAY 177 6:30:2 100 7 40 .000 0.0



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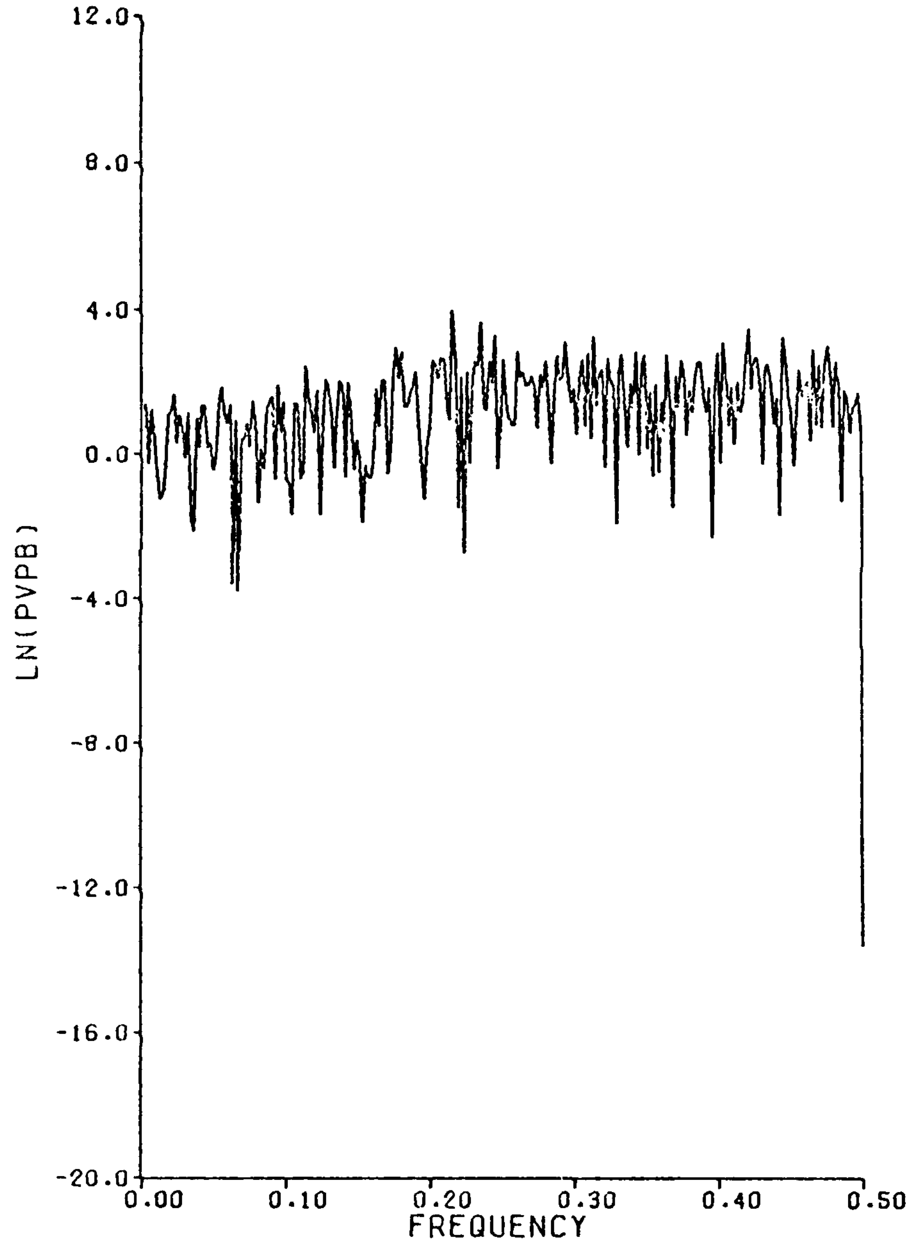

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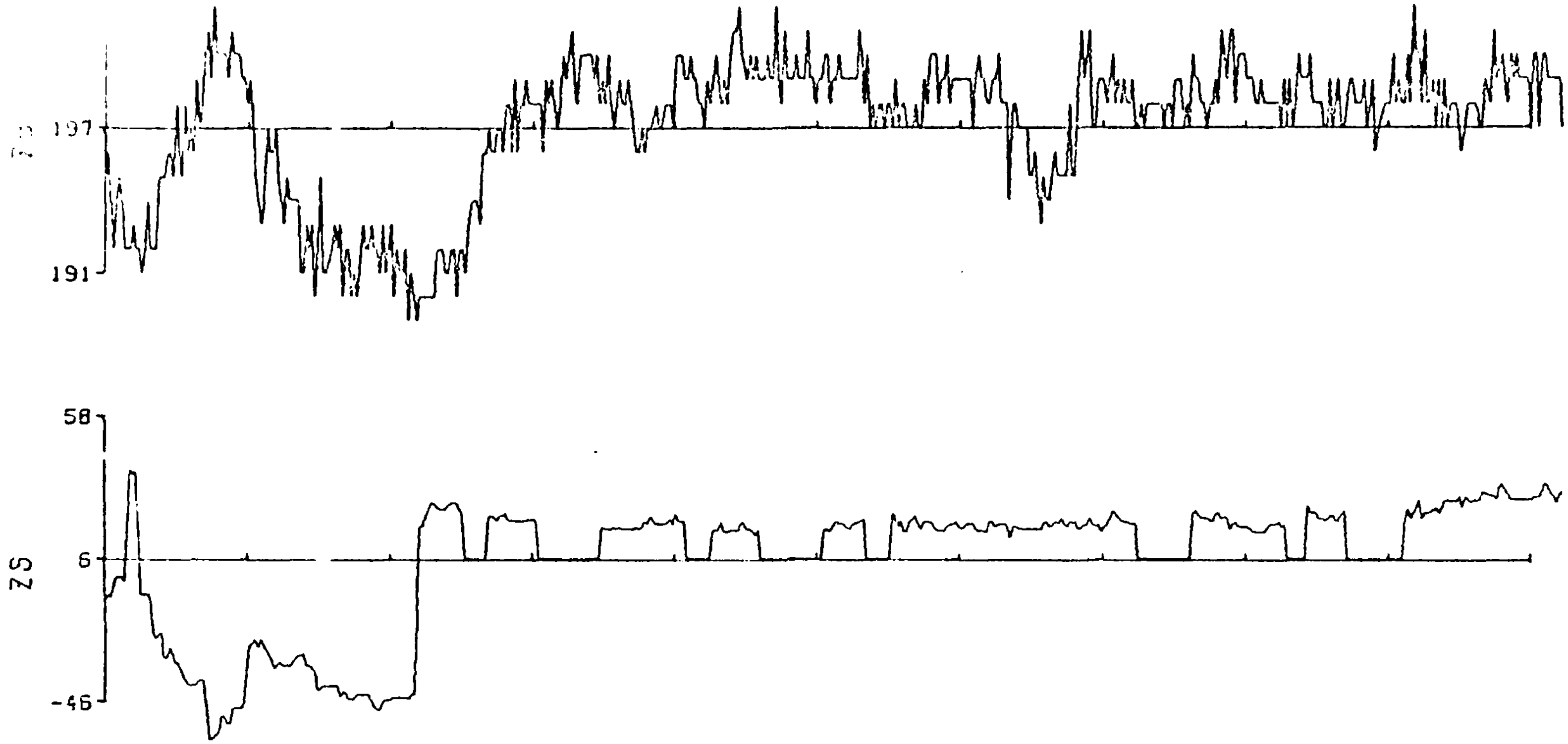

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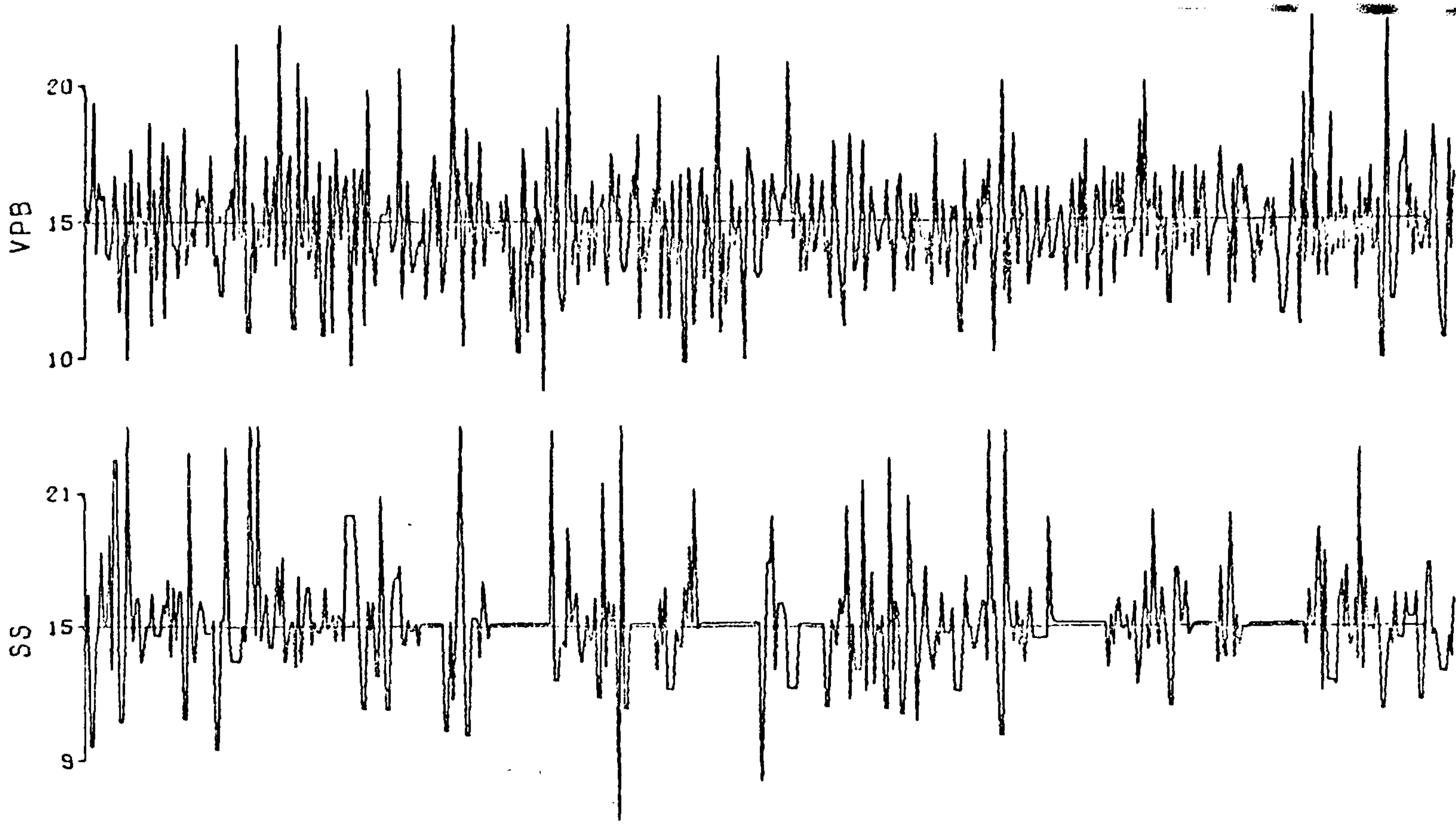

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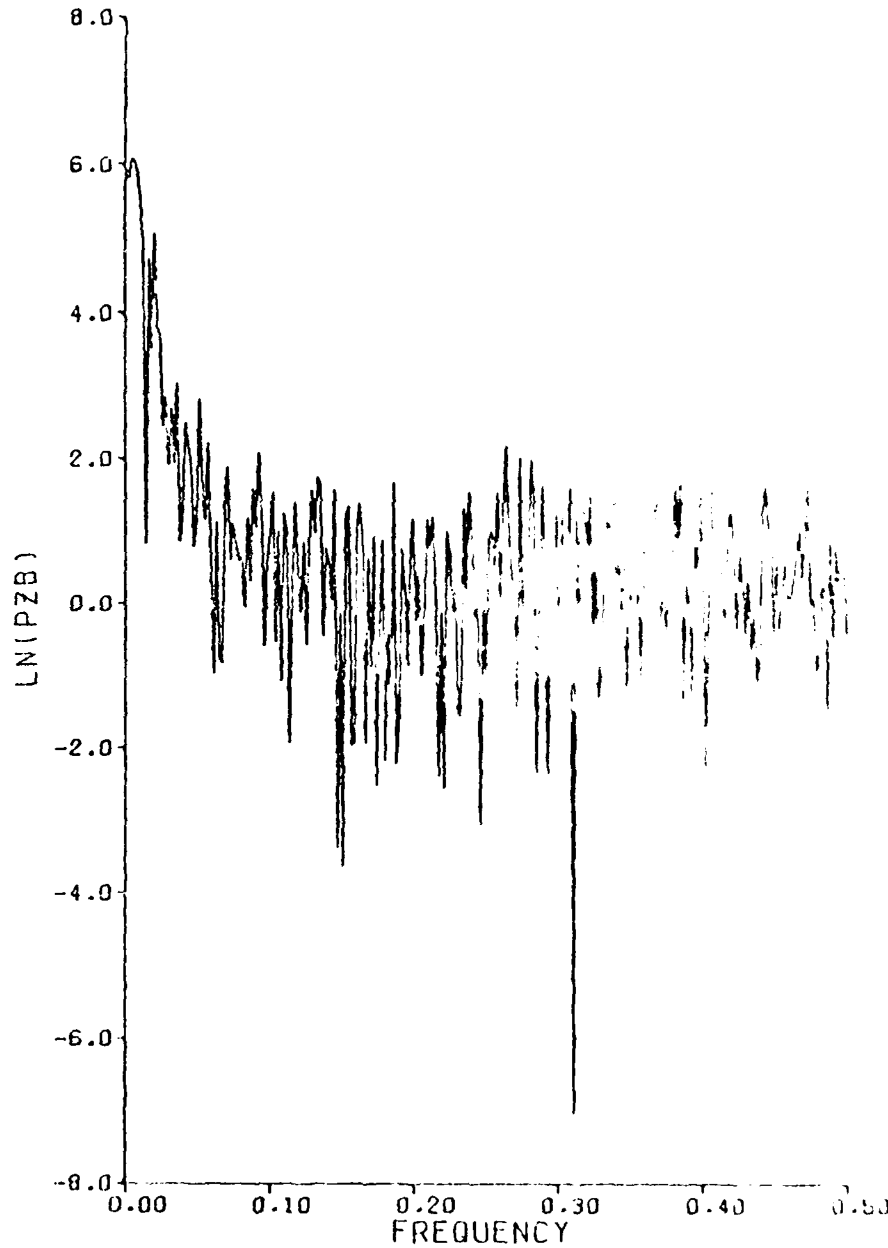

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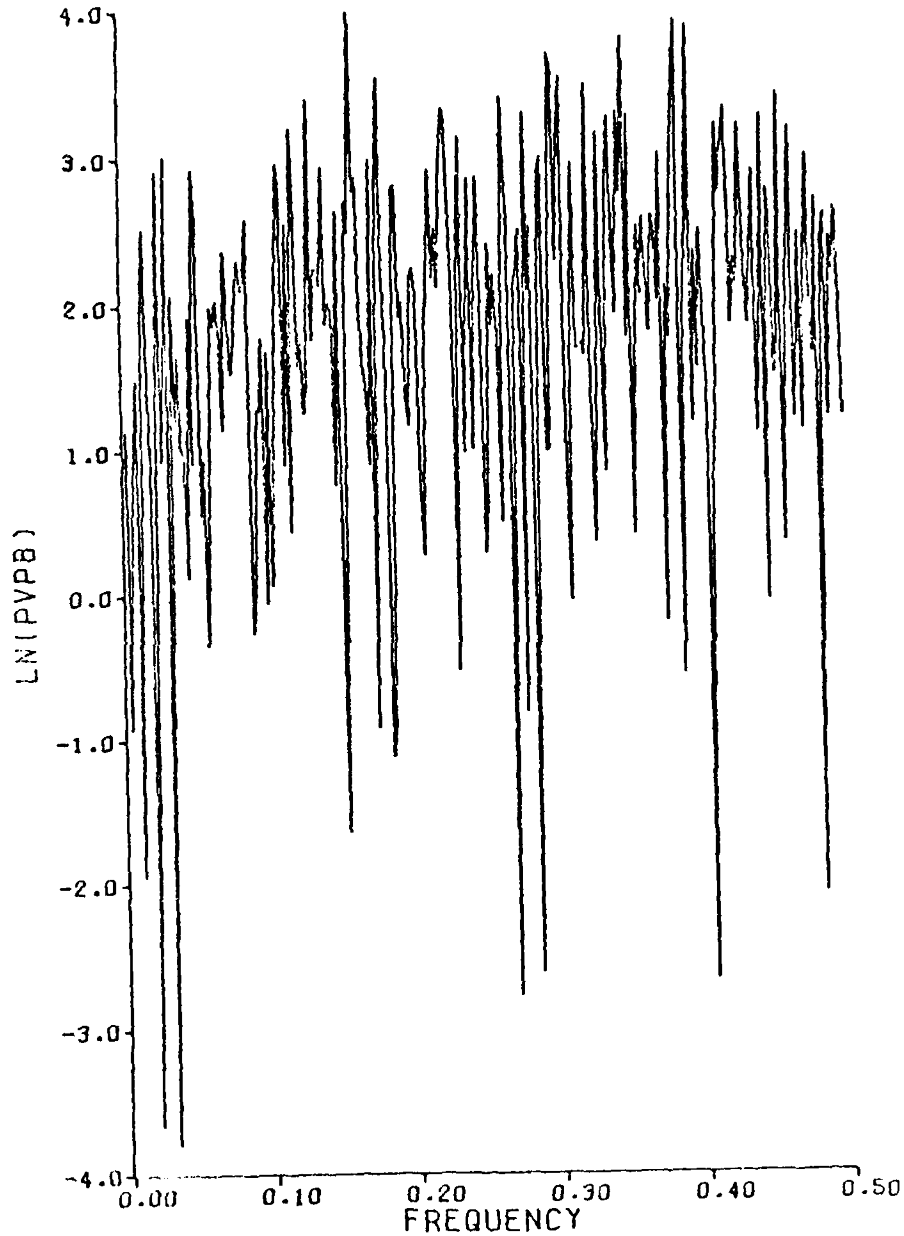

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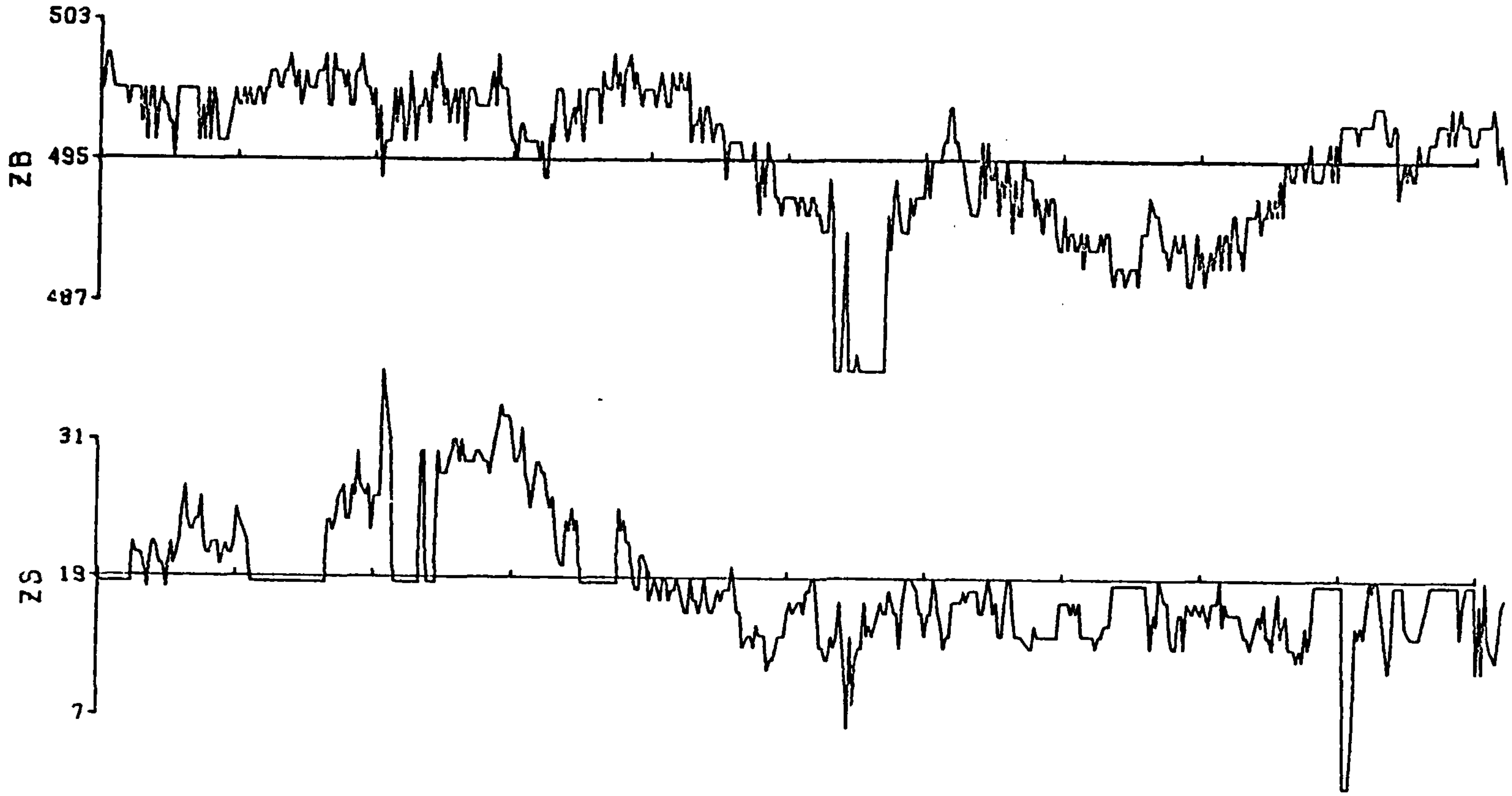

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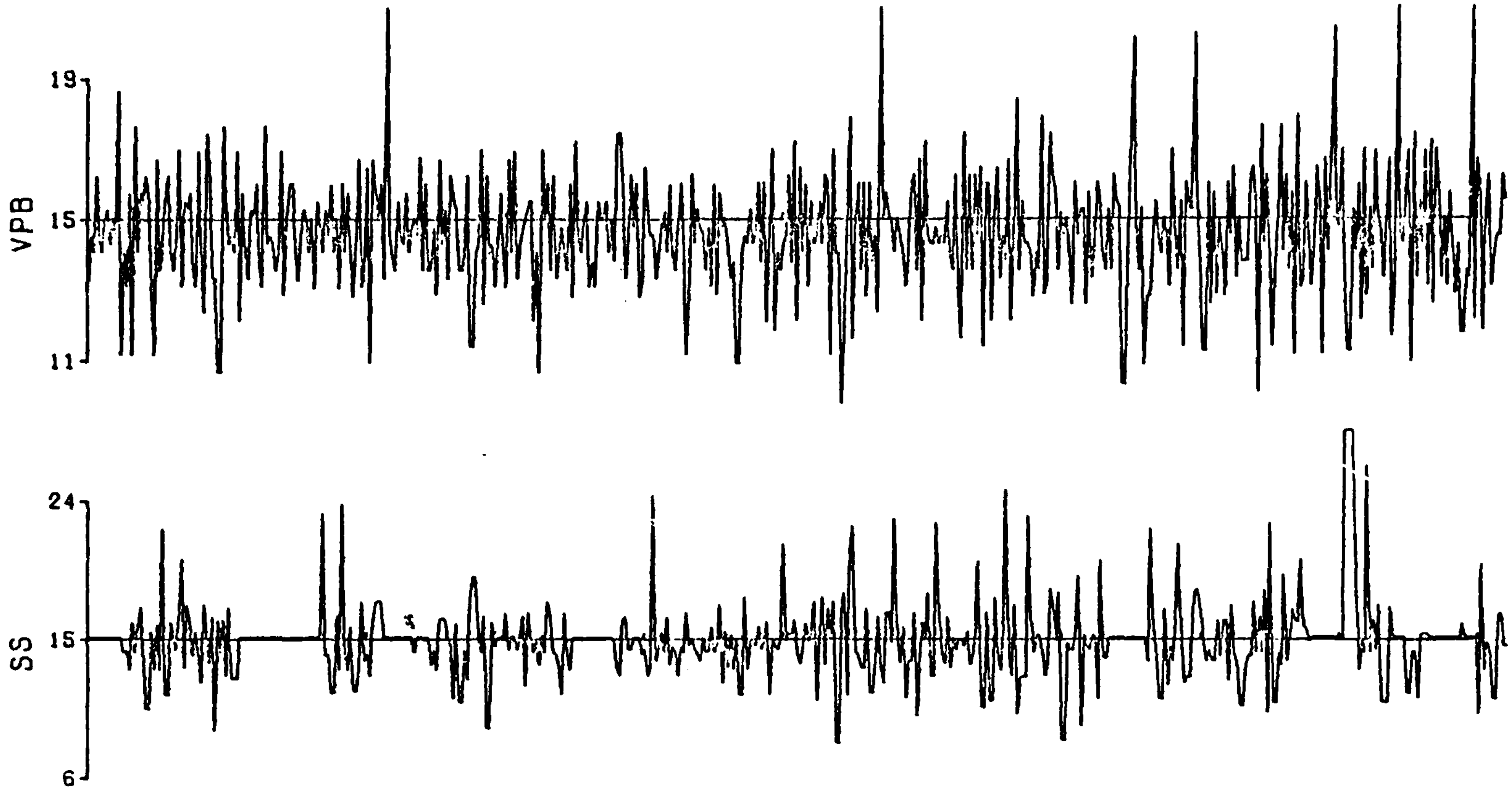

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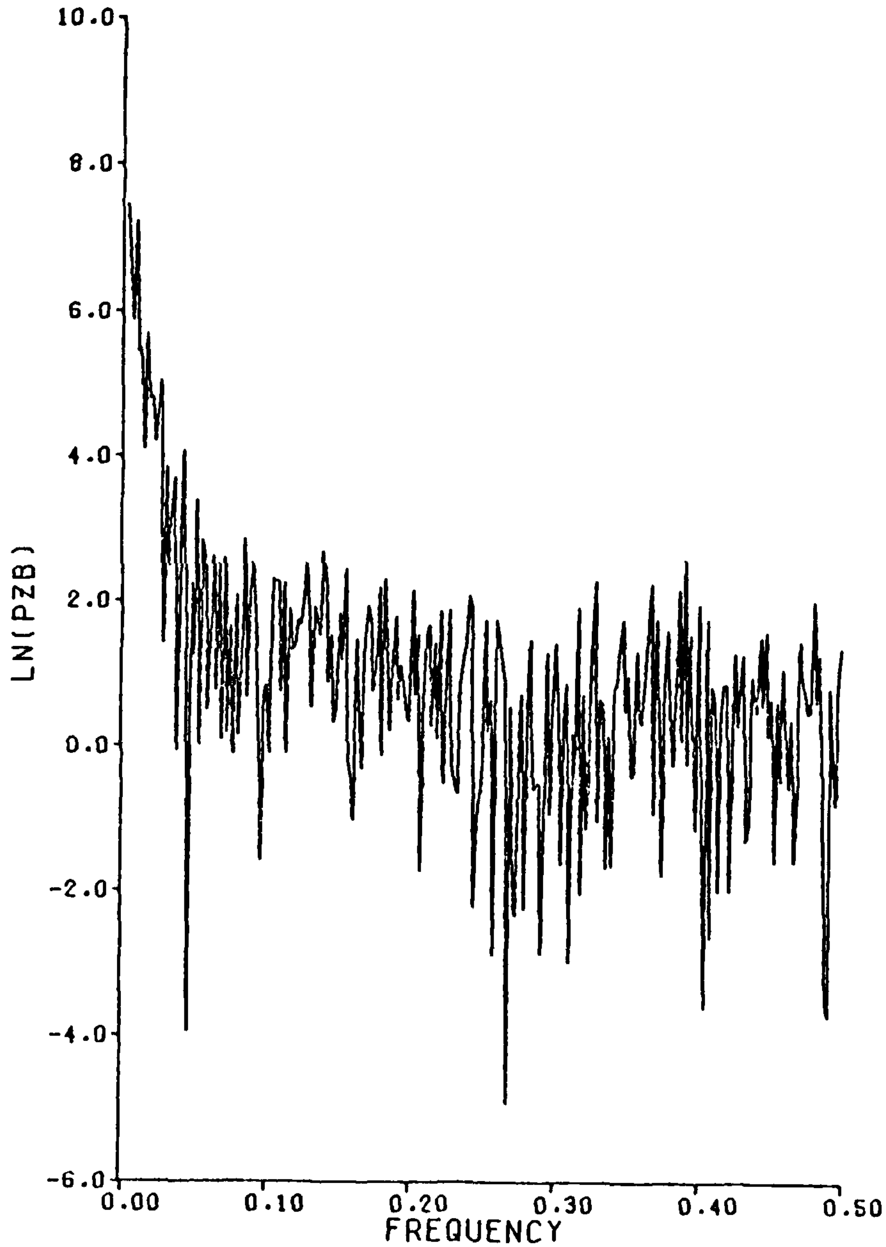

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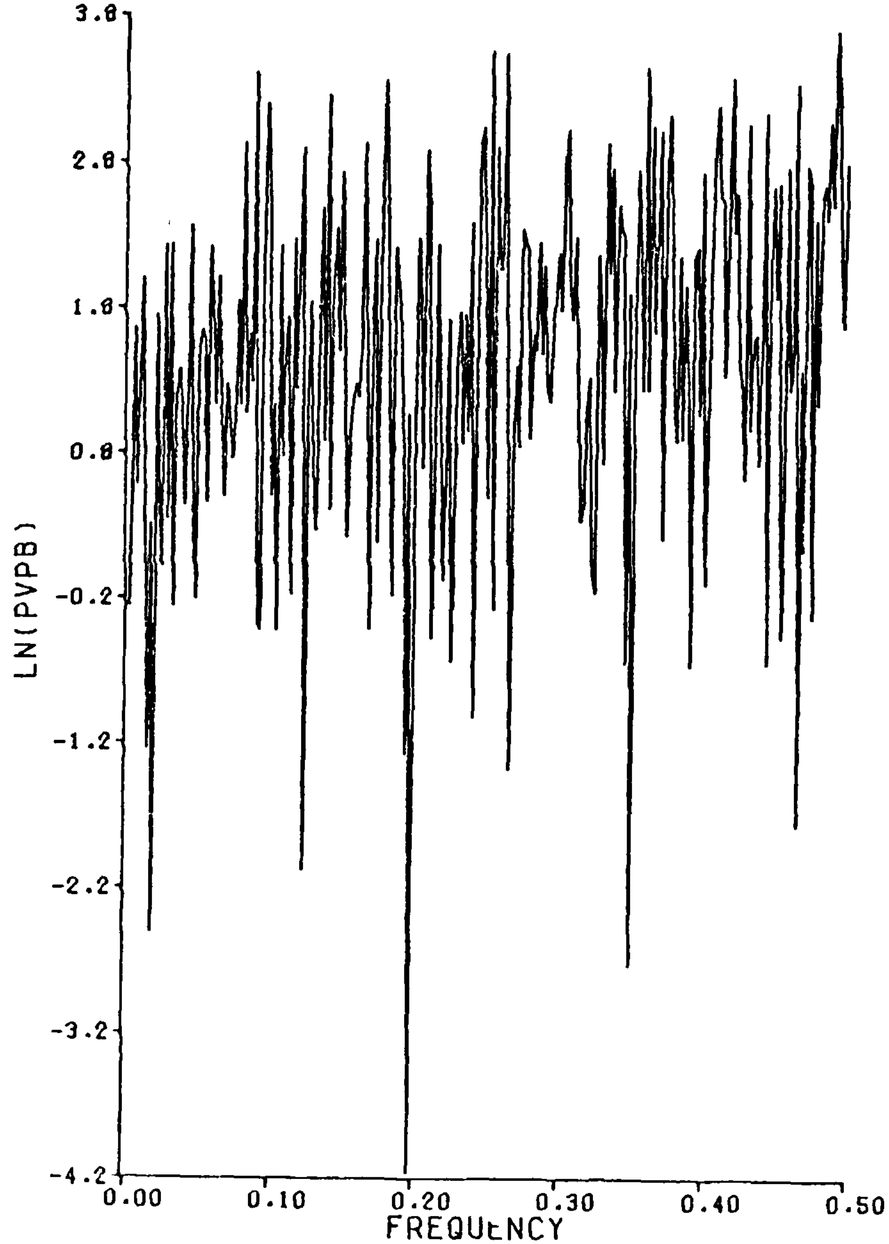

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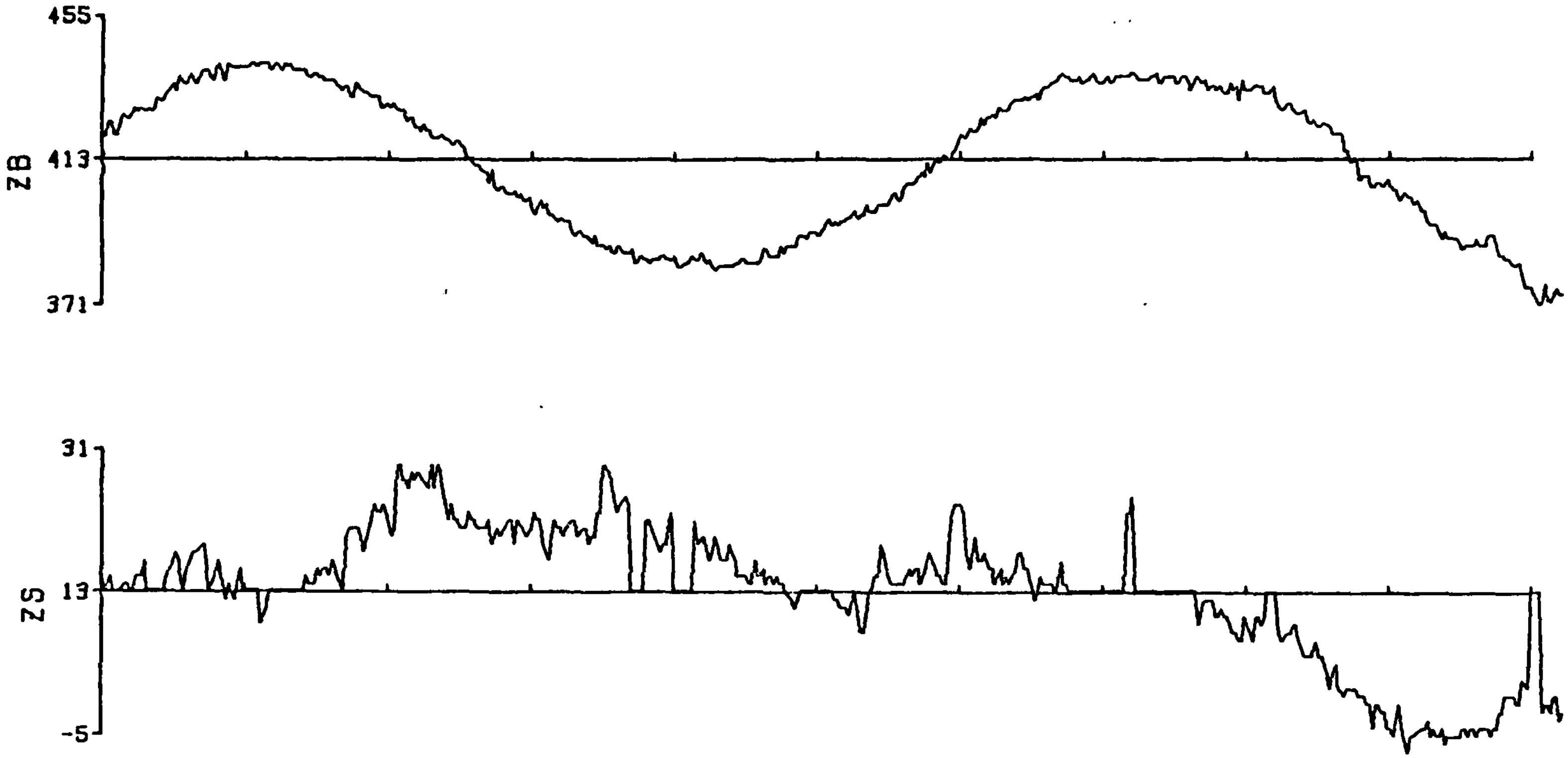

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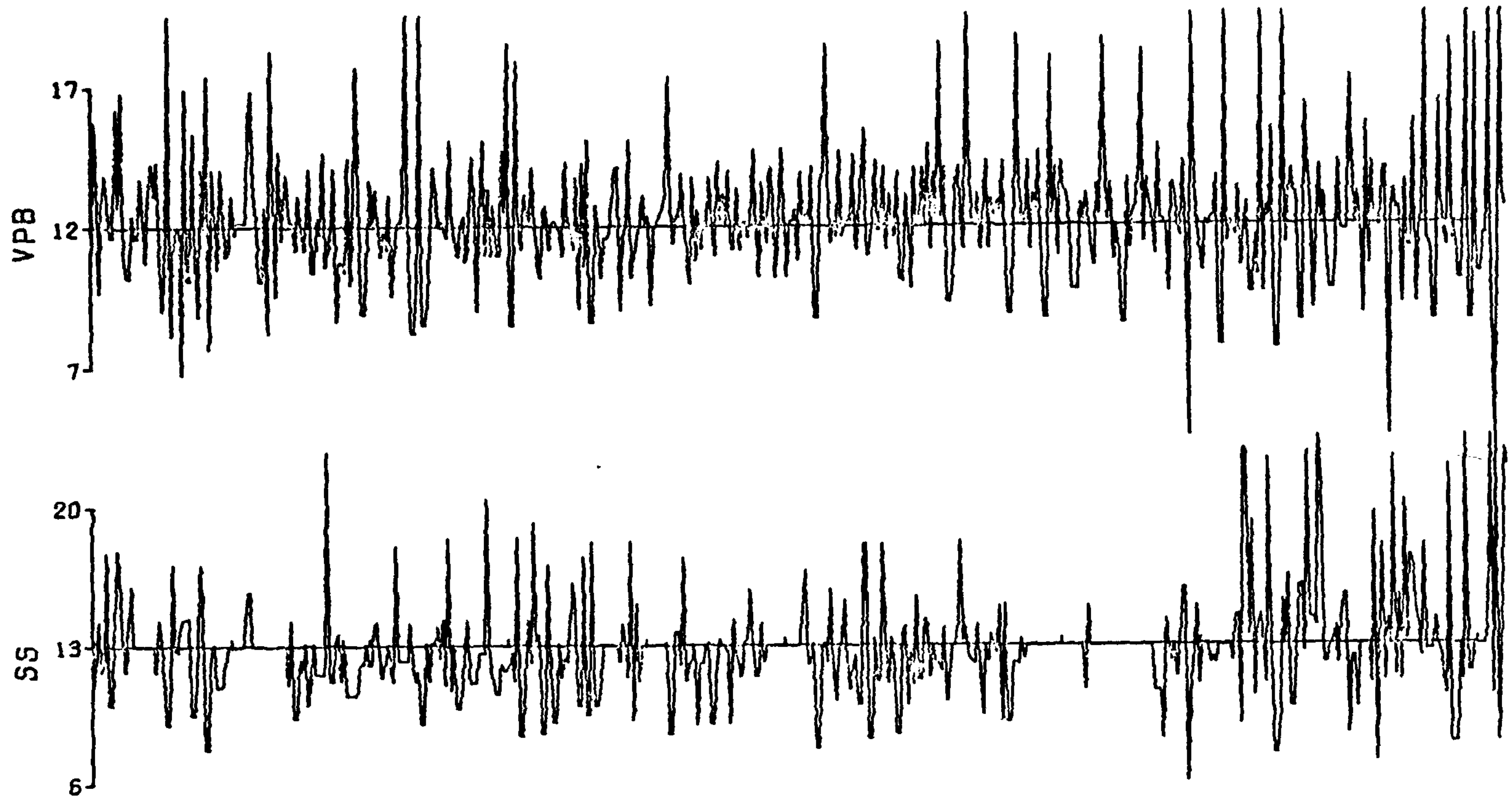

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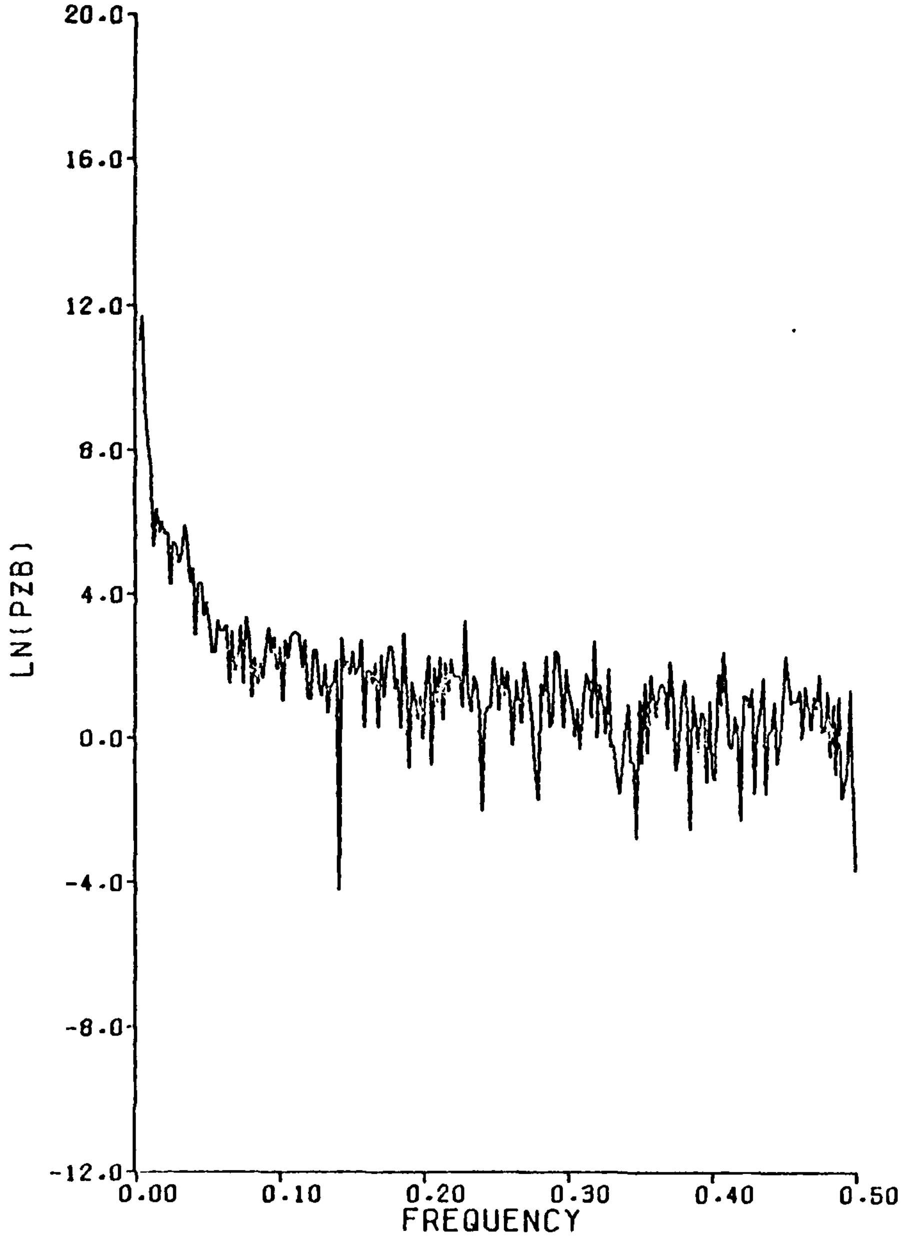
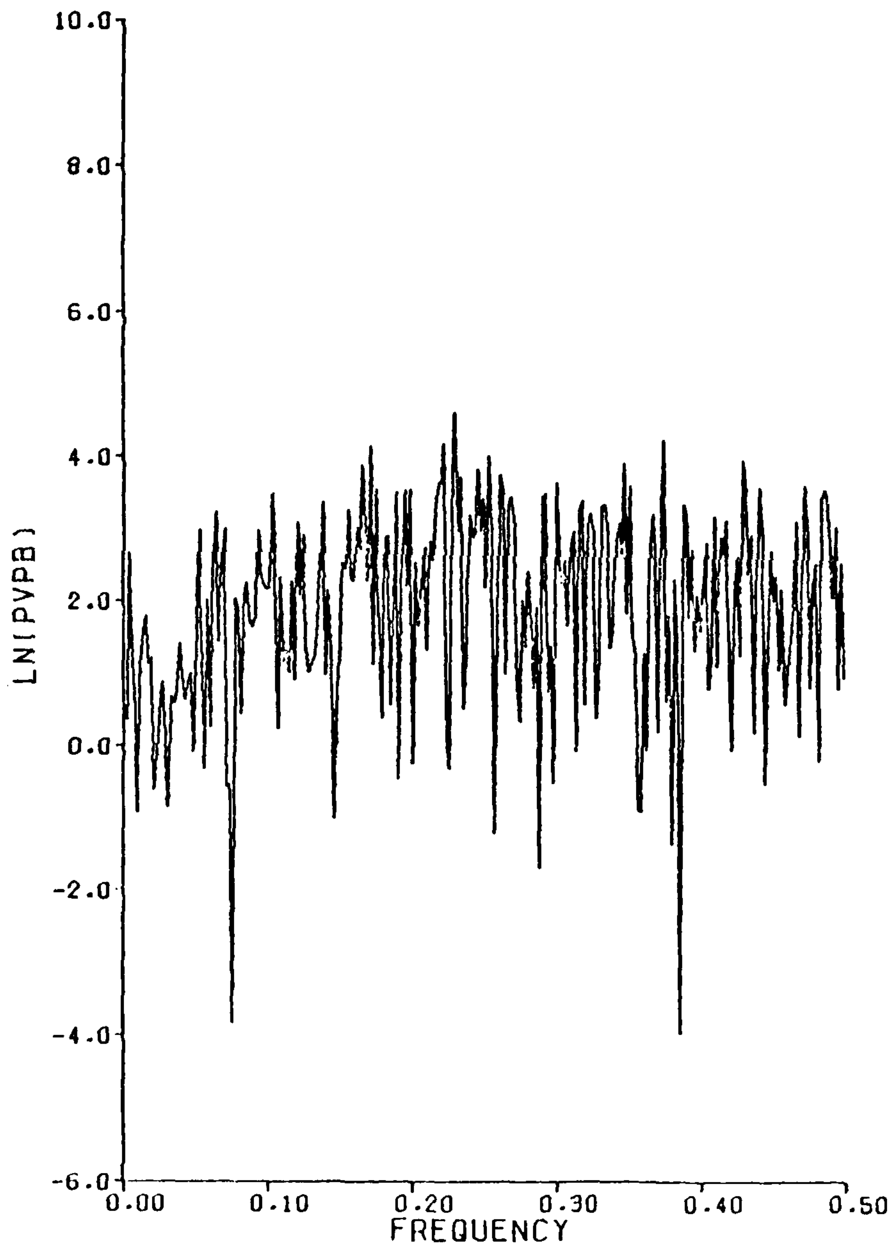


DE3 DAY 179 1:50:30 500 7 125 .003 1.0



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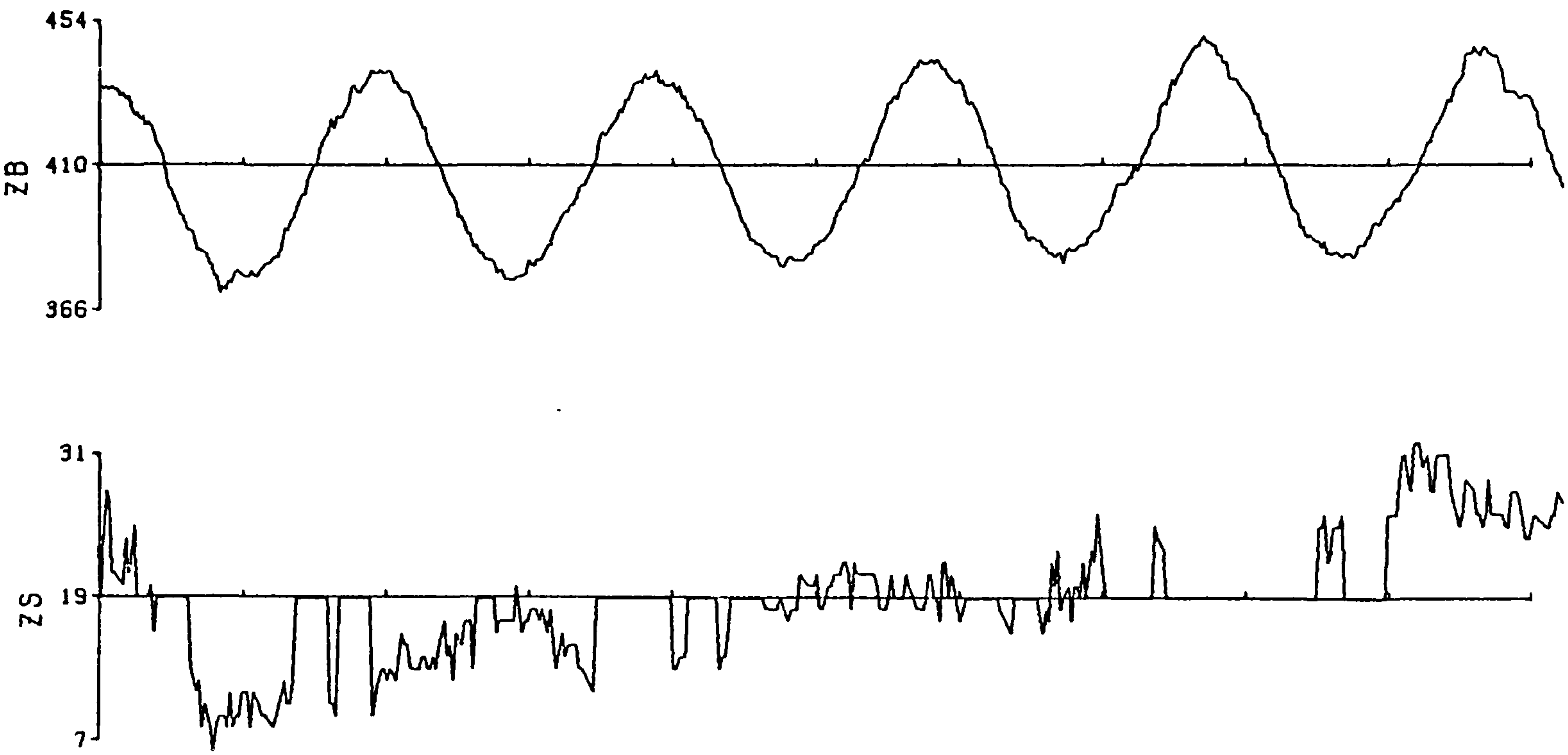
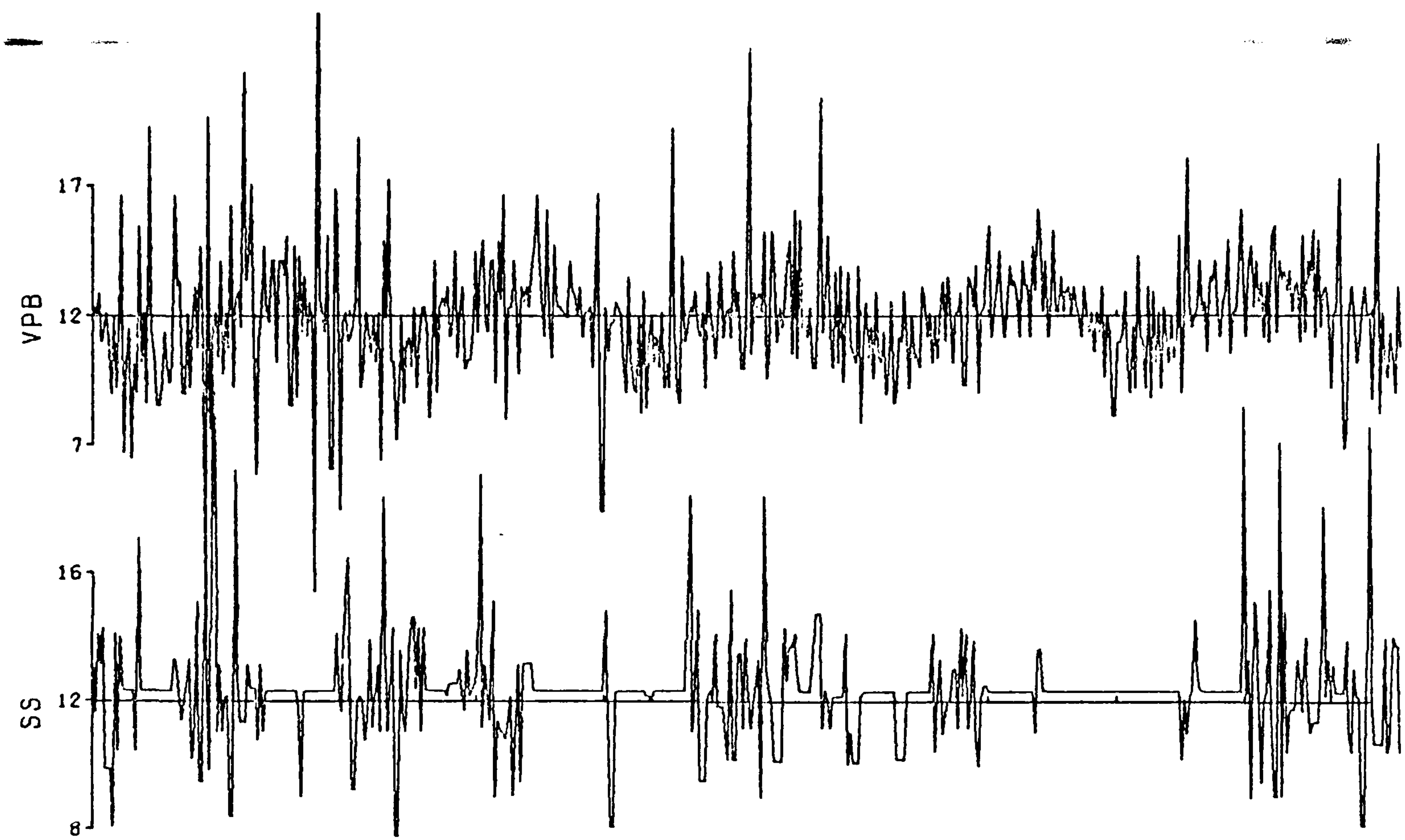


JK2 DAY 179 3:34:5 500 7 125 .010 1.0



JK2 DAY 179 3:34:5 500 7 125 .010 1.0

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AN EVALUATION OF THE HYDRODYNAMIC STABILITY AND OPERATIONAL SUI--ETC(U
SEP 80 T H HESSELBACHER, G J RANES N00014-79-C-0803
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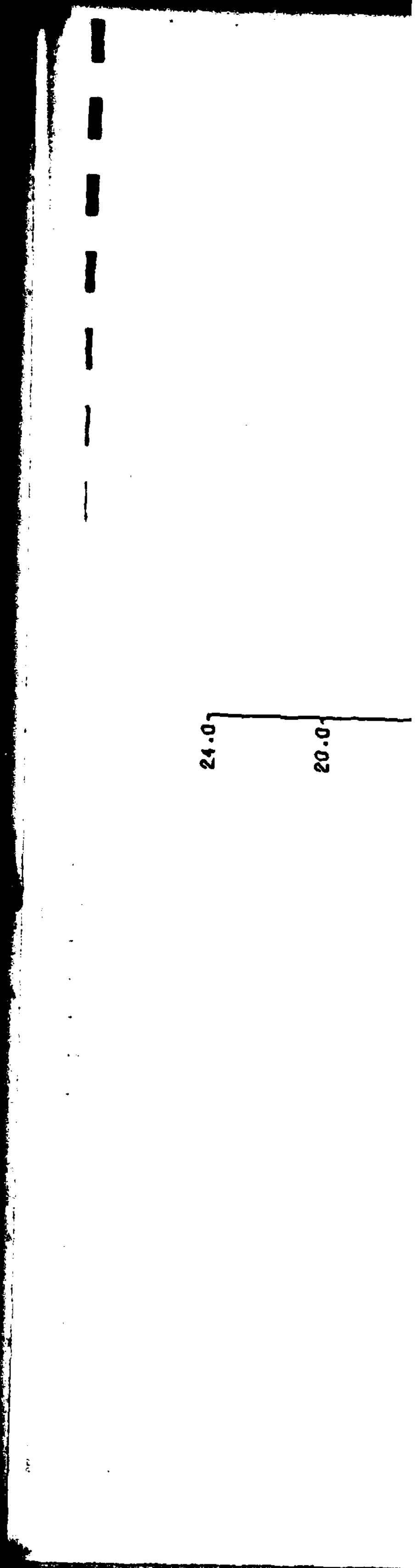

1.0 2.8 2.5 3.2 2.2 3.6 2.0 4.0 1.1 1.8 1.25 1.4 1.6

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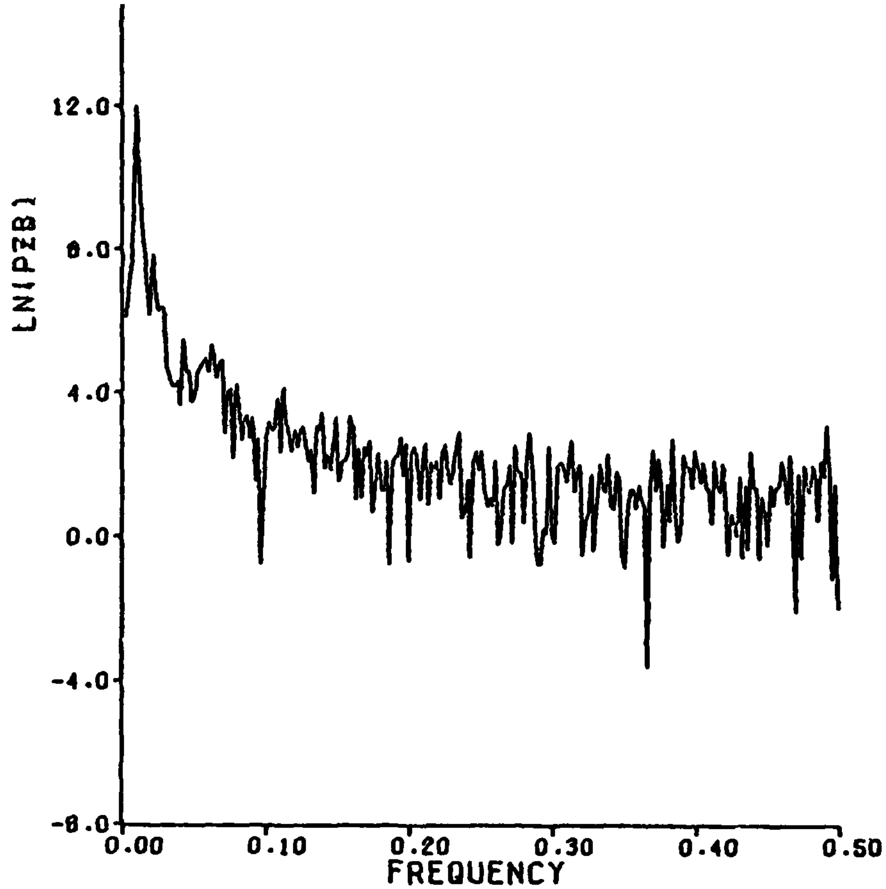
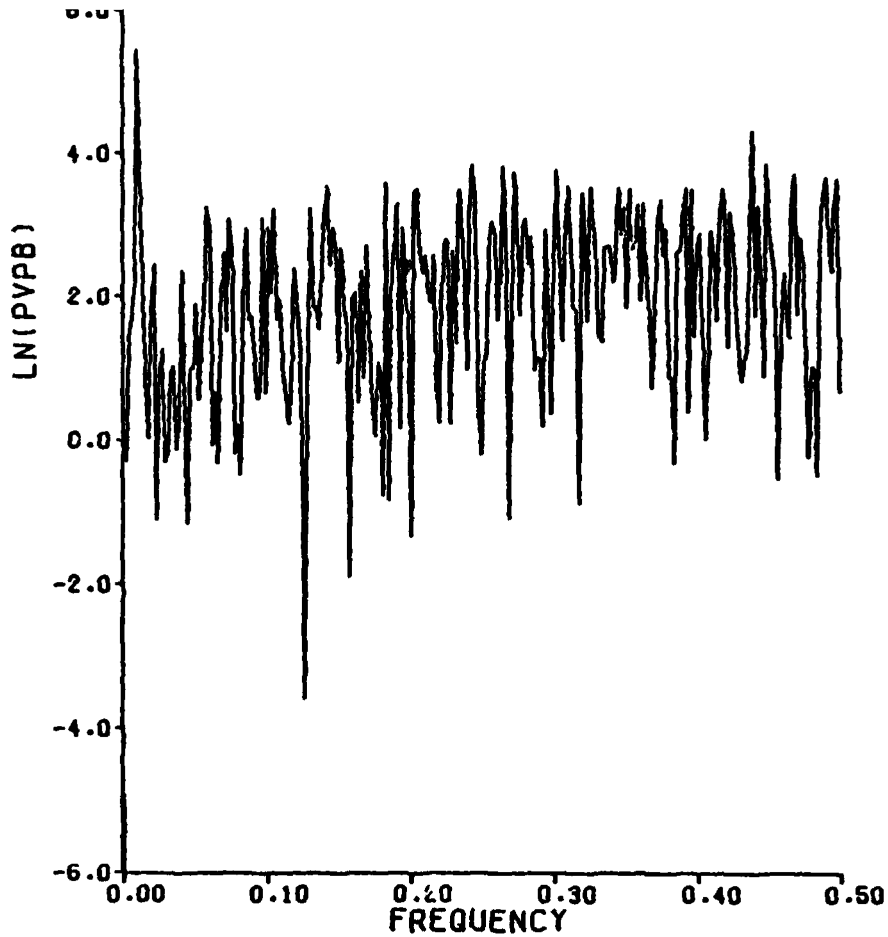


JK2 DAY 179 3:34:5 500 7 125 .010 1.0



JK2 DAY 179 3:34:5 500 7 125 .010 1.0

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